Test-Retest Repeatability of a Rapid Aortic Wave Velocity Technique

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Introduction

Stiffening of the central elastic arteries has been reported to be a potent and independent predictor of cardiovascular mortality and morbidity[1] and has been linked with increased risk among the elderly and in patients with diabetes, heart failure, end-stage renal disease and metabolic syndrome.

Most noninvasive methods to measure central arterial stiffness suffer significant methodological drawbacks. For example, direct aortic distensibility measurements necessitate an estimate of central pulse pressure, which is known to vary from that observed peripherally. Likewise, wave velocity (an index of stiffness) determined between distal sites (e.g. carotid and femoral locations) often involves a gross estimate of the actual propagation distance, and ultimately represents an average of several disparate vessel segments.

The validity of studies employing arterial stiffness data, especially interventional trials of drug therapy or lifestyle alterations, is strongly dependent on measurement reproducibility. For one popular technique (ultrasonic carotid-femoral wave velocity), the test-retest intraclass correlation was found to be 0.62, with an average wave velocity disparity of 1.7 m/s between the two determinations.[2] Alternative techniques yielding rapid and reproducible localized assessment of central arterial stiffness would be of major clinical benefit.

We have developed a one-dimensional time-of-flight MR sequence to measure aortic wave velocity (AWV) in the descending thoracic aorta with an acquisition time of one cardiac cycle.[3] The accuracy of the method has been demonstrated using compliant tube phantoms, and the in vivo beat-to-beat coefficient of variation is 7.6%.[4] In this study, we examined the test-retest reliability of the technique between two independent AWV determinations, in order to discern possible effects of changes in subject positioning and MR operator on AWV reproducibility.

Methods

Ten apparently healthy subjects (5 male/5 female, age range 22 – 57 years, mean age 31 ± 12.8 years) underwent two independent AWV measurement sessions on the same day. In each case, the investigator positioning the subject in the magnet and operating the scanner for the second exam was not the same as for the first. After attachment of ECG electrodes for cardiac gating, subjects were placed supine on a standard spine array receiver coil, and centered in the 1.5 T magnet using the xiphisternum as an anatomic landmark. After acquiring axial and sagittal scout images, the AWV sequence was executed in synchrony with the onset of cardiac systole. The one-dimensional sequence employed repeated simultaneous RF excitation of two thin sections perpendicular to the aorta, and separated by 84 mm. Slice selection and frequency encoding were oriented parallel to the vessel long axis. Aortic blood flow produces time-of-flight displacements of RF-tagged blood at the two (upstream and downstream) sites, which are recorded in the acquired echoes as frequency shifts. Analysis of these shifts allows reconstruction of the flow waveforms at the two sites. The spatial separation of the tagged sites (84 mm) divided by the temporal offset of the flow waveforms yields the wave velocity. Data were transferred to a personal computer and analyzed with custom software developed using MatLab. For each individual session, seven AWV trials were acquired; after eliminating the highest and lowest result, the remaining five measurements were averaged to yield the final result (in m/s).

The intraclass correlation coefficient (ICC) was used to assess test-retest reliability of AWV. The standard error of the measurement (SEM) with 95% confidence bounds was determined using the formula: $SEM_{95\%}=1.96[SD_{AVG}*(\text{square root of } 1 - ICC)]$. A Bland-Altman plot was constructed to visualize differences in test-retest AWV values. A p-value <0.05 was considered significant.

Results

The overall mean AWV values for exams 1 and 2 were 5.56 (± 0.54) and 5.61 (± 0.54) m/s, respectively. The ICC for the two AWV values was 0.97 ($p<0.001$). The $SEM_{95\%}$ for AWV was ± 0.18 m/s. The Bland-Altman bias and limits of agreement were –0.08 (+0.28/-0.44) m/s, respectively.

Conclusion

This MR sequence allows a rapid, reliable and more reproducible means to examine aortic stiffness than do conventional methods.

References

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