Carotid Artery Pulse Wave Velocity Measurement by Cardiovascular Magnetic Resonance
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Introduction
Pulse wave velocity (PWV) is the rate at which a pressure and flow wave moves along a blood vessel. PWV has not previously been measured in the carotid artery by cardiovascular magnetic resonance (CMR). PWV is inversely related to vascular compliance. Arterial stiffness increases with age and a range of arterial diseases including atherosclerosis and systemic hypertension.[1],[2] PWV can be measured non-invasively by aplanation tonometry, ultrasound and more recently by CMR.

CMR has several advantages over ultrasound in that full 3D visualisation of the vessel is possible enabling the imaging plane to be placed perpendicular to the vessel in a reproducible location. Velocity data can be acquired virtually simultaneously in two imaging planes and the path length (distance between the two imaging planes) can be measured precisely.

CMR has previously been limited by poor temporal resolution which is a crucial factor, given the short path length involved. However we have developed a new interleaved sequence using maximal gradient and RF performance which has enabled us to reach a temporal resolution of 3.8 ms.

Using maximum gradient and RF performance, and inverting the slice-selection gradient for velocity-encoding, TR 1.9 ms was achieved, giving TR 3.8 ms for each imaging plane. Voxel size was FE 1.8 mm by PE 2.4 mm by SLT 8 mm, echo time 1.1 ms and flip angle 15°.

The mean velocity in the region of interest for each phase was calculated. Mean velocities were plotted against time (Figure 2). A best fit straight line was fitted to the velocity points between 25% and 75% of the maximum. The pulse arrival time was defined as the point where a line drawn back from these two points intersected with the baseline. The pulse arrival time was determined for both planes. The path length between planes was measured from transverse time of flight images. PWV was calculated from the path length divided by the difference in arrival times (PWV = distance/time).

To determine intra-scan reproducibility, data was acquired twice for each vessel.

Results
Mean PWV was 5.1 m/s with a range of 3.3 to 8.5 m/s. A Chronbach alpha value for intra-scan reproducibility was 0.77. This suggests a high degree of consistency between the image acquisitions. The mean path length was 54 mm (range 39-60 mm).

Method
We recruited 7 healthy volunteers (3 female, 4 male, age range 28-35). We performed CMR imaging of the carotid arteries using a Siemens Sonata 1.5-T scanner with purpose-built two element phased-array surface coils.

Non-segmented through-plane phase velocity mapping (at 85 cm/s VENC) was applied to two planes transecting the common carotid and the internal carotid arteries (Figure 1). We aimed to maximise the path length while keeping both planes within the area of optimal coil response. In the first three subjects we used geometric transverse planes, but subsequently we imaged each side separately using planes perpendicular to the vessel to maximise through plane velocity. Data acquisition for the two slices was interleaved for 80 cine frames per slice within each cardiac cycle, and repeated with velocity encoding on the subsequent cycle. Velocity images were reconstructed by subtraction of the phase images, with a further subtraction of background velocity errors (measured by imaging the same planes in a stationary phantom).

Conclusion
We have demonstrated in this preliminary study that PWV can be measured in the carotid arteries by CMR over very short path lengths. Intra-study reproducibility is good. The wide range of PWVs found requires further investigation and explanation. This may be physiological; however a major source of error is in determining the pulse arrival time from the velocity-time curves, and other methods such as peak-second-derivative are being investigated.

References

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