Validation of high temporal resolution spiral phase velocity mapping of coronary artery blood flow against Doppler Flowire

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Purpose

The temporal pattern of coronary artery flow velocity through the cardiac cycle provides important information about coronary haemodynamics and atherosclerotic disease state.[1] The current 'gold standard' for coronary artery velocity assessment is the Doppler Flowire which is inserted directly into the coronary artery during X-ray contrast angiography, an invasive technique which uses ionising radiation and which has a small but significant risk of serious complication. In this study, we perform a direct comparison of coronary artery blood flow velocities measured with breath-hold high temporal resolution spiral phase velocity mapping against Doppler Flowire measurements in a small cohort of patients attending for clinical fluoroscopic coronary angiography studies.

Methods

A retrospectively gated interleaved spiral sequence was developed on a 3T Skyra scanner (Siemens) using 1-1 water excitation and allowing full k-space coverage in 8 spiral interleaves of 12ms duration. Phase map subtraction of datasets with symmetric bi-polar velocity encoding gradients resulted in velocity maps with a through-plane phase sensitivity to flow of +/- 30cm/s. Data were acquired in a breath-hold of 17 cardiac cycles (including 1 dummy cycle) with a slice thickness 8mm, spatial resolution 1.2 x 1.2 mm (reconstructed to 0.6 x 0.6 mm) and repeat time 19ms. Proximal coronary artery phase velocity maps were acquired in 4 patients (3 RCA and 4 LAD arteries, all angiographically normal) who had previously undergone invasive Doppler Flowire assessment as part of an X-Ray coronary angiography study. MR acquisitions were repeated twice for assessment of inter-scan reproducibility. For each vessel, the mean through-plane motion-corrected MR velocities at all timepoints were plotted against the equivalent Flowire velocities (averaged over 16 cardiac cycles). If necessary, the profiles were first time-shifted to take into account small differences in data triggering between the two techniques. The correlation between the two profiles was assessed using simple linear regression analysis.

Results

One patient (1 LAD and 1 RCA) was excluded because of poor quality invasive data. Figure 1 (a) shows an example early diastolic proximal RCA (top) and LAD (bottom) MR magnitude image and velocity map. The Flowire velocities through the cardiac cycle are shown in (b) and the MR measured velocities from repeated acquisitions are shown in (c). In (d), the Flowire data are plotted directly against the MR data. On average, MR velocities were 47% less than the Flowire velocities but the range of underestimation was large (12% – 69%). The correlation between the MR and Flowire data, however, was high, with R^2 values of .47, .66, .91, .79 and .85 for the 5 vessels studied (mean R^2 = .73). The subject with the lowest R^2 value had the fastest and most variable heart rate. As demonstrated in (c), repeat breath-hold acquisitions show a high degree of similarity in the MR data.

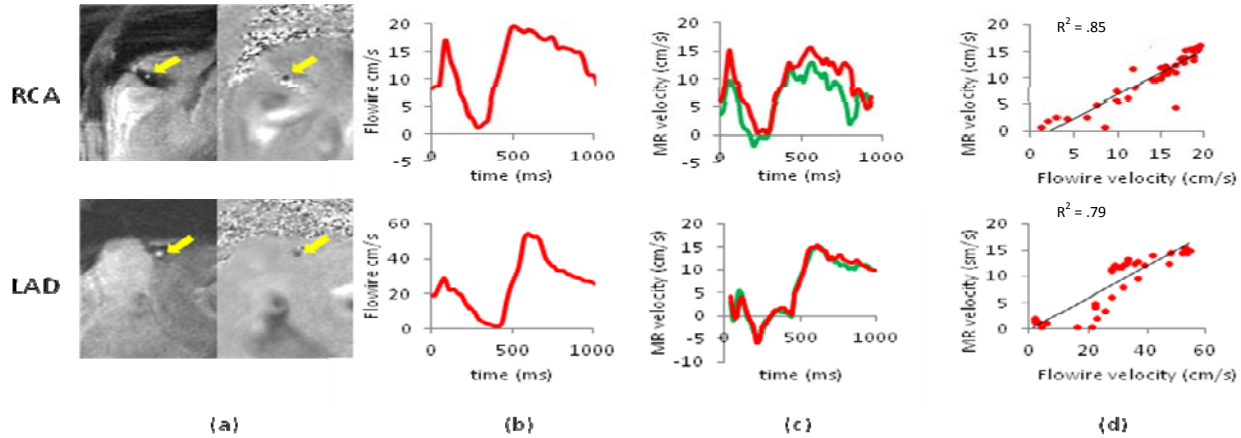

Figure 1: *Example early diastolic RCA (top) and LAD (bottom) magnitude image and velocity map from spiral phase velocity acquisitions (a), together with Doppler Flowire data (b), MR flow velocities through the cardiac cycle (red/green profiles from different breath-hold acquisitions for assessment of inter-scan reproducibility) (c) and plots of MR measured velocities against Flowire measured velocities (d).*

Discussion and Conclusion

As expected, absolute measures of velocity obtained with the Doppler Flowire are higher than MR measurements as Doppler determines the peak velocity in a small sample volume, rather than the mean velocity over the cross-sectional area of the vessel. It is also possible that a heightened physiological state at the time of the invasive study results in higher Doppler coronary artery flow velocities. However, temporal flow profiles measured in the proximal coronary arteries using breath-hold interleaved spiral phase velocity mapping in this small study are highly similar to those measured with Doppler Flowire and in addition, the flow patterns have high inter-scan reproducibility. We conclude that spiral phase velocity mapping of coronary artery blood flow has the potential to assess temporal flow patterns in the proximal coronary arteries.

References

[1]Davies et al, Circulation 2006; [2]Keegan et al, JMRI 2004;