Inter breath-hold reproducibility of high temporal resolution spiral phase velocity mapping of coronary artery blood flow and in vivo validation against Doppler flow wire

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Purpose

While blood flow in the majority of arteries peaks in systole, the rhythmic squeezing of the coronary arteries and microcirculation as the heart beats results in left anterior descending artery (LAD) flow being diastolic-predominant while for the right coronary artery (RCA), there is approximately equal flow in systole and diastole. These temporal flow patterns are affected by disease and can provide important information on disease state.[1] The 'gold standard' for coronary artery velocity assessment is the Doppler flow wire which is inserted directly into the artery under X-Ray fluoroscopic guidance. In this study, we perform a direct comparison of coronary flow velocities measured with breath-hold high temporal resolution spiral phase velocity mapping against Doppler flow wire measurements. The inter breath-hold reproducibility of MR assessment of blood flow parameters is also assessed.

Methods

A retrospectively gated interleaved spiral sequence was developed on a 3T Skyra scanner (Siemens) with full k-space coverage in 8 interleaves (12ms duration). Phase map subtraction of datasets with symmetric bi-polar velocity encoding gradients resulted in a flow sensitivity of +/- 30cm/s. Data were acquired in a 17 cardiac cycle breath-hold (includes 1 dummy cycle) with spatial resolution 1.4 x 1.4 mm (reconstructed to 0.7 x 0.7 mm) and repeat time 19ms. Proximal coronary artery velocity maps were acquired in 11 patients (5 RCA and 10 LAD arteries) who had previously undergone invasive Doppler flow wire assessment as part of a clinical X-Ray coronary angiography study. MR acquisitions were repeated for assessment of reproducibility. For each vessel, the mean MR velocities at all timepoints were plotted against the equivalent flow wire velocities and the correlation between the two was assessed using simple linear regression. The inter breath-hold reproducibilities of repeated MR measurements of mean velocity (MV) and peak systolic and diastolic velocities (PSV and PDV) were determined as the mean (+/- SD) of the signed differences between paired breath-hold values.

Results

In the 15 vessels studied, MR coronary velocities were ~40% of the Doppler flow wire velocities and the correlation between them was moderate (R^2 = 0.71, 0.53 and 0.69 for PSV, PDV and MV respectively) (Figure 1). For *individual* vessels (Figure 2), the temporal flow profiles were highly similar and MR measured velocities through the cardiac cycle correlated well with Doppler flow wire velocities (mean R^2 = 0.81 +/- 0.12, range 0.60 – 0.95). The inter breath-hold reproducibility of MR velocity measurements was high (PSV: -1.7 +/- 15.9 mm/s, PDV: -3.5 +/- 11.6 mm/s, MV: -2.4 +/- 6.9 mm/s).

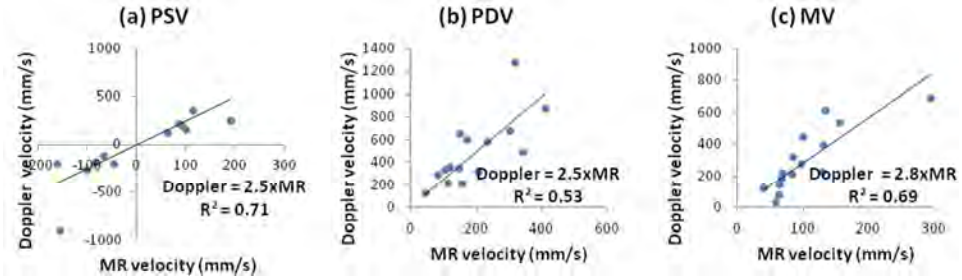

Figure 1: *Doppler flow wire versus MR measures of coronary flow velocity in 15 proximal coronary arteries: (a) peak systolic velocity (PSV), (b) peak diastolic velocity (PDV) and (c) mean velocity through the cardiac cycles (MV).*

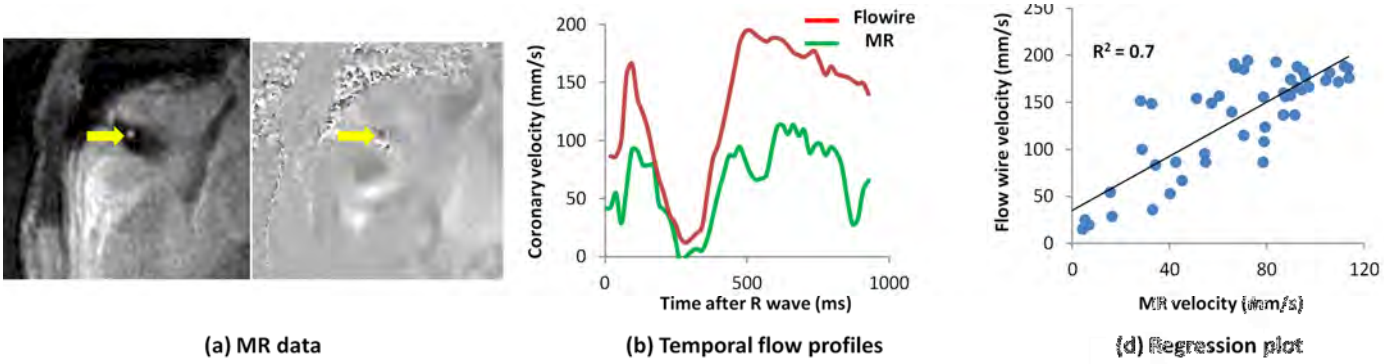

Figure 2: *Example early diastolic RCA (arrow) magnitude image and velocity map from a high temporal resolution spiral phase velocity acquisition (a) Plot of MR and flow wire coronary velocity against time (b) and a regression plot of MR velocities against flow wire velocities (c). MR underestimates velocity but the shape of the temporal flow profile correlates well with that obtained invasively.*

Discussion and Conclusion

As expected, absolute measures of velocity obtained with Doppler flow wire 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. However, temporal flow profiles measured in the proximal coronary arteries using breath-hold interleaved spiral phase velocity mapping are highly similar to those measured with Doppler flow wire and in addition, the flow patterns have high inter breath-hold 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 JE et al, Circulation 2006; 113: 1768- 78.