Right ventricular velocities over the entire cardiac cycle measured with high resolution spiral phase velocity mapping: results, reproducibility and comparison with the left ventricle

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Target Audience: Scientists and clinicians interested in right ventricular motion, inter and intra ventricular dyssynchrony.

Purpose: Phase velocity mapping (PVM) is capable of accurately and reproducibly measuring myocardial velocities in the left ventricle (LV)[1]. However, analysing right ventricular (RV) motion is more difficult because of the thinness of the free wall and its asymmetrical geometry. Currently, the most commonly used technique for assessing RV velocities and function is Tissue Doppler Imaging (TDI) where the high temporal resolution allows the detailed analysis of fine features of motion (small peaks in velocity during isovolumic contraction (IC) and isovolumic relaxation (IR) [2], for example). However TDI is restricted by inadequate acoustic windows and cannot comprehensively assess velocities over the entire RV. This study aims to establish that high resolution spiral PVM is capable of reproducibly measuring RV free wall velocities and that it potentially has a future role in assessing RV function. Furthermore, the ability to measure both peak and time-to-peak (TTP) values in both LV and RV from a single acquisition means that spiral PVM could efficiently assess inter as well as intra ventricular dyssynchrony, an important step for understanding the effects of cardiac resynchronisation therapy [3].

Methods: K-space is covered with 13 spiral interleaves (12ms duration, TR 21ms). Navigator-gated reference and velocity-encoded data (25cm/s through-plane) are acquired in consecutive cardiac cycles following a single dummy cycle. The acquired spatial resolution is 1.4x1.4x8mm (reconstructed to 0.7x0.7mm). Retrospective gating allows full coverage of the cardiac cycle with 60 phases per RR-interval (reconstructed temporal resolution 14-20ms). Basal, mid and apical short-axis slices were acquired in 10 healthy volunteers on a Siemens Skyra 3Tesla scanner. The mid slice was also acquired on a second day to assess inter-study reproducibility. Longitudinal velocities averaged over both the RV free wall and the LV were extracted and peak velocities and TTP velocities were measured and normalized to a fixed systolic (350ms) and diastolic length (650ms). The reproducibility of mid slice values was determined as the mean (+/- SD) of the signed differences of the two measurements made on different days. Paired t-tests were used to determine whether there are any significant differences between LV and RV values.

Results: The high spatial resolution allowed the analysis of the thin RV free wall in all slices and in all volunteers on both occasions – example data are shown in Figure 1. Mean+/-SD velocities and TTP velocities for systolic, early diastolic and late diastolic peaks in the basal, mid and apical short axis slices are shown in Figure 2, and are highly consistent between subjects. Inter-study reproducibilities of RV peak systolic, early diastolic and late diastolic velocities were excellent (0.21±1.31, 0.15±1.13and 0.69±2.39cm/s respectively) as was the interstudy reproducibility of the corresponding TTPs (11.6±78.2, -13.1±30.6and -6.67±19.9 respectively). The high temporal resolution of the sequence allowed detection of IC and IR (Figure 1) in 22 and out of 40 velocity-time curves. Peak systolic velocity occurs earlier for the LV than the RV (P<0.005 for all levels) and the RV peak is broad leading to a comparatively large SD for TTP in all slices. Basal peak diastolic (P<0.01) and apical peak systolic (P<0.05) velocities are significantly higher in the LV than RV, whereas the late diastolic peak is higher in RV than LV in both basal (P<0.01) and apical slices (P<0.001). All other velocity differences are non significant (P>0.05).

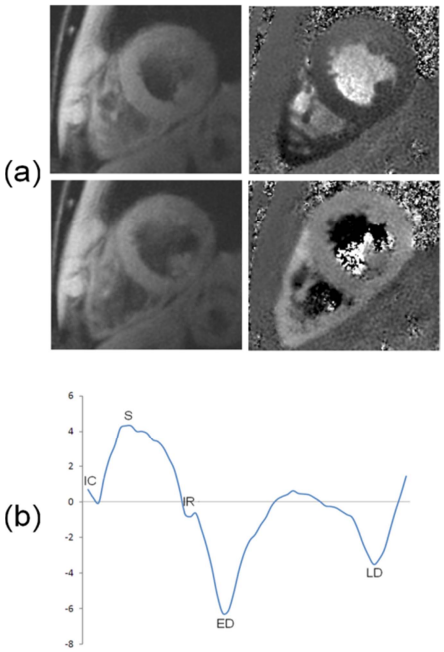

Figure 1 (left): *(a) Example magnitude images (left) and velocity maps (right) at the time of peak systolic (S, top) and peak early diastolic (ED, bottom) velocity. Both LV and RV walls are clearly seen. (b) Example global RV wall velocity-time curve. All 5 phases of right ventricular motion (IC, systole (S), IR, early diastole (ED) and late diastole (LD)) observed with TDI can be seen.*

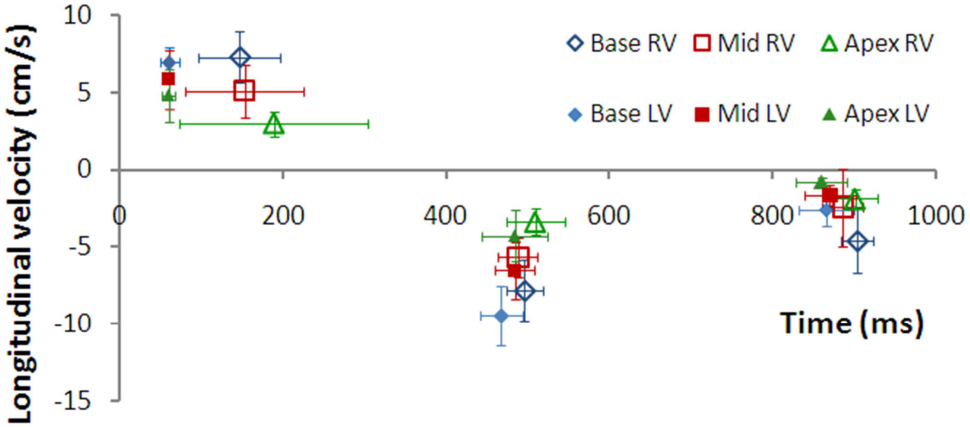

Figure 2 (above): *Mean +/- SD velocity and TTP of S, ED and LD peaks for LV and RV. While LV and RV follow qualitatively similar velocity patterns throughout the cardiac cycle, there are some significant differences in peak and TTP values (see Results).*

Discussion and Conclusions: PVM can be used to measure RV free wall velocities with a high degree of reproducibility. Due to the flexibility of MR, PVM is potentially a more flexible and comprehensive modality for assessing regional RV motion than TDI. Peak systolic and diastolic velocities show a general trend to being higher in the LV than RV; however the opposite is true for the late diastolic peak caused by the contraction of the atria. This could perhaps be due to the lower resistance to motion offered by the thin RV when compared to the thicker LV. The ability to measure both left and right ventricular velocities simultaneously and reproducibly could make this technique a useful tool for those undergoing biventricular pacing for example.

References [1]Foll,2010,Circ;[2]Horton,2009,JASE; [3] Cazeau, 2000, Heart