Regional analysis of 3-directional myocardial velocities acquired in a breath-hold with efficient retrogated spiral phase velocity mapping

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Introduction: Myocardial phase velocity mapping (PVM) has previously been shown capable of quantifying regional myocardial motion [1,2]. However Cartesian k-space coverage in combination with respiratory gating has lead to long and unpredictable scan times, while prospective gating leads to 'dead times' in the cardiac cycle where imaging cannot be performed. We have developed a PVM technique that combines efficient spiral coverage of k-space with retrospective cardiac gating to allow 3 directional PVM of the entire cardiac cycle in a single breath-hold. The feasibility of using this technique for rapid assessment of regional myocardial motion is demonstrated.

Methods: The sequence (TR=30ms) consists of five interleaved spiral k-space paths (23ms), one interleaf being acquired per cardiac cycle. Reference and 3-directional velocity encoded data (15cm/s in-plane, 25cm/s through-plane) are acquired in consecutive cardiac cycles following a single dummy cycle (breath-hold duration 21 cardiac cycles). A black-blood suppression pulse (6ms) is output on alternate phases to reduce blood flow artefacts. Retrospective gating allows reconstruction of 40 phases (reconstructed temporal resolution 19-31ms depending on heartrate) covering the entire cardiac cycle with an acquired spatial resolution of 2.4x2.4x8mm (reconstructed 1.2x1.2x8mm). Basal, mid and apical short axis slices where acquired in 6 healthy volunteers on a Siemens Skyra 3T scanner. Radial, circumferential and longitudinal velocities throughout the cardiac cycle were calculated pixel-wise and as an average over six semi-automatically segmented regions of the left ventricle.

Results: Figure 1 shows regional radial velocities throughout the cardiac cycle in the basal, mid and apical short axis slices of an example volunteer together with colour-coded radial velocities at selected time points. Regional radial velocities are shown below and demonstrate the different patterns of motion found at different levels in the left ventricle. Ventricular expansion resulting from atrial contraction at the end of the cardiac cycle (the atrial 'kick') is clearly seen at all levels. Figure 2 shows global radial, circumferential and longitudinal velocities in the mid slices of all volunteers and the time courses demonstrate low inter-subject variability. Figure 3 shows regional radial velocities normalised to end-systole in the mid slice for all 6 volunteers demonstrating similar regional variations in temporal patterns for all. These graphs are plotted through systole and early diastole only, as the length of diastole (and hence the timing of the atrial kick) is highly subject specific.

Conclusion: This efficient spiral PVM technique allows regional 3 directional myocardial velocities to be acquired in a single breath-hold with reasonable temporal resolution (33ms), while retrospective ECG gating allows analysis of the entire cardiac cycle including atrial contraction. Future work will include reducing the blurring due to off-resonance and implementing parallel imaging to reduce the breath-hold duration.

[1] Jung et al., JMRI 2006 [2] Delfino et al., Radiology 2008

Figure 1

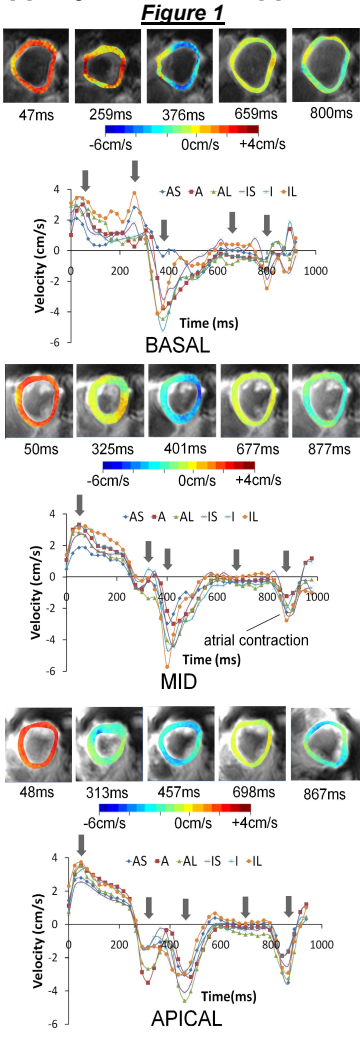

Figure 2

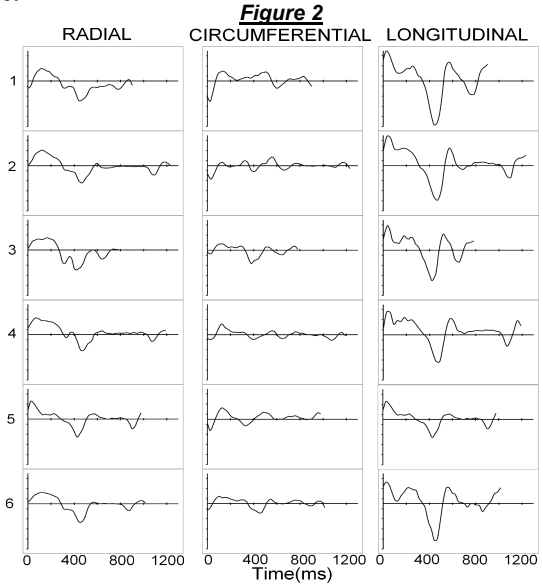

Figure 3

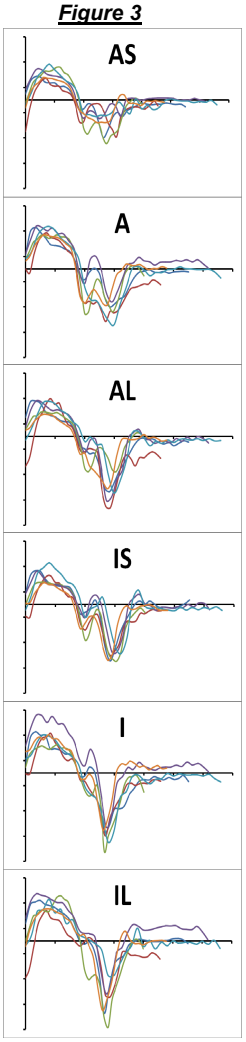

Figure 1 : Magnitude images with colour-coded overlays showing radial velocities in the basal, mid and apical slices of an example volunteer at five time points (top) with corresponding regional myocardial velocity time curves (bottom). Grey arrows show the time points of the radial colour plots. (AS=antero-septal, A=anterior, AL=antero-lateral, IS=infero-septal, I=inferior, IL=infero-lateral).

Figure 2: Global radial (left), circumferential (middle) and longitudinal (right) velocities over the entire cardiac cycle in the mid short axis slice in all 6 subjects. Longitudinal and radial temporal patterns show low inter-subject variability (apart from the length of diastole). Circumferential patterns are most subject-specific and strongly dependent on exact slice location [1]. (Velocity scale -9cm/s to + 6cm/s).

Figure 3: Regional, radial velocities in the 6 segments of the mid-ventricular slice for all 6 volunteers through systole and early diastole. Time courses are normalised to end-systole and show considerable inter-subject similarities. The length of diastole (and hence the timing of the atrial contraction phase) is highly subject-specific and so end-diastole has been omitted to highlight systolic and early diastolic similarities. (Velocity scale -7cm/s to +5cm/s).