Radial and Circumferential Strain using feature tracking from Cine SSFP Imaging with Compressed Sensing at Rest and with MRI Exercise Ergometry

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Target Audience: Myocardial strain imaging is an important tool to quantitate deformation. This data is relevant to researchers and clinicians looking to apply new post-processing feature tracking algorithms, with application to rest-stress Cardiac MRI.

Purpose: Myocardial deformation imaging with strain imaging using echocardiographic speckle tracking now has prognostic data to inform clinical management, and is entering routine clinical practice and guidelines. MRI strain using grid tagging (eg SPAMM/HARP) is time consuming to analyze, and has not had widespread clinical uptake for deformation imaging. Recently, feature tracking on standard steady state free precession imaging has been developed for the quantitation of MRI strain data. We performed quantitative exercise ergometry using an MRI bicycle combined with ultra-fast multi-slice segmented ECG-triggered CINE TrueFISP imaging featuring sparse, incoherent sampling and a compressed sensing image reconstruction, and applied radial and circumferential strain using feature tracking.

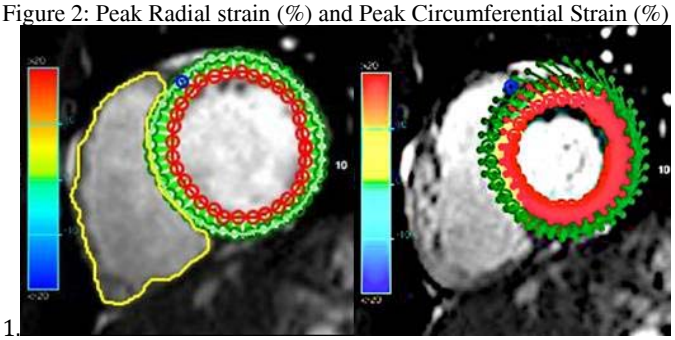
Methods: Two elite athletes were imaged at rest and during exercise on a Siemens AERA 1.5T system using a Lode MRI pedal ergometer. CMR acquisitions were performed using a "CV_sparse" approach: ECG-triggered segmented CINE TrueFISP sequences (TE1.1;TR56 at rest and TR30 during exercise, in-plane spatial resolution 2.4 x 3.4 mm) with an mSENSE type acceleration factor of 4. Images of the left ventricle in short axis view were acquired in suspended respiration for CV_sparse at rest and again following incremental exercise at specified workloads (25,50,100 Watts or maximum tolerated). Strain maps were calculated using 50 cords at end-systole and end-diastole using the same, standard epicardial and endocardial contours as drawn for diastolic and systolic volume analysis (Figure 1). Peak radial and circumferential strain (%), time-to-peak strain (ms), maximal strain rate (1/s), systolic wall thickening (%) and quantitative wall motion (mm) were analysed in AHA-16 segment models using Circle Cvi42 Tissue Tracking software module (version 4.1.5 prototype WIP) (Figure 2). Comparisons between rest and stress metrics were made with a paired T-test (MedCalc).

Results: At 100 watts of workload**,** LVEF increased from 54 to 64% at 100 watts, and RVEF increased from 43% to 55%. Images at 200watts were less reliable due to motion and rapid heart rate reduction during breath-holding. At 100 Watts, the segmental peak radial strain increased from 28% to 37% (p=0.002), peak circumferential strain -14.9% to -19% (p=0.0003), radial time-to-peak 424ms to 298ms (p<0.001), circumferential time-to-peak 434ms to 297ms, strain rate 1.5 to 2.6 sec^{-1}, wall motion 7.6mm to 11.4mm (p=0.009) and SWT 44% to 53% (p=0.13 NS). Analysis time was <1 minute, substantially shorter than published analysis time for SPAMM/HARP processing (~10minutes).

Discussion and Conclusion:

Quantitation of myocardial deformation is feasible using feature tracking on SSFP imaging acquired both at rest and during physical exercise. Use of ultra-fast ECG-triggered Cine SSFP imaging with compressed sense reconstruction allows rapid acquisition during exercise, with excellent image quality for feature tracking analysis. Feature tracking is a novel tool for the quantitative analysis of myocardial deformation, without the need for additional image acquisition and using the same contours as for LVEF analysis, rendering it a useful and clinically applicable technique.

Figure 1: LV short axis CV_sparse image at end-diastole (left) and end-systole (right) with feature tracking overlays.
Figure 2: Peak Radial strain (%) and Peak Circumferential Strain (%) at 100 Watts in AHA 16-segment model.

1. 

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