Myocardial tissue characterization from cine bSSFP signal waveforms and longitudinal shortening identifies edematous and fibrotic myocardium in agreement with gadolinium enhanced imaging

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Target Audience: Cardiac MRI researchers and clinicians with a focus on gadolinium free tissue characterization. **Purpose**: To use signal waveforms generated by cine balanced state free precession (bSSFP) CMR and longitudinal shortening to identify myocardial tissue that enhances with gadolinium. **Introduction**: Late gadolinium enhancement (LGE) CMR is the standard of care technique for identification of edematous and fibrotic myocardium, however concerns over nephrotoxicity have motivated the development of non-contrast tissue characterization methods. Cine bSSFP is ubiquitously used to image left ventricular structure and global function, and demonstrates changes in signal intensity during the cardiac cycle resulting from thru-plane motion. Fibrotic and edematous myocardium demonstrates elevated signal intensity at end diastole and reduced longitudinal shortening compared to healthy tissue. We examined whether measurement of changes in myocardial bSSFP signal waveforms coupled with measurement of longitudinal shortening could characterize myocardial tissue similar to LGE. **Methods**: Forty patients (32 men, 8 women, average age 49 ± 16 years) referred for clinical CMR examination along with 10 healthy volunteers (5 men, 5 women, average age 27 ± 2 years) participated in the research protocol. All imaging was performed on a 1.5T Siemens Aera scanner (Erlanger, Germany) using a 12 channel chest array coil and an 8 channel spine coil. In each individual, one mid-ventricular slice was selected and cine bSSFP images were acquired using a prospectively gated acquisition with the number of cardiac phases optimized to fill the cardiac cycle. Additional parameters included TR/TE = 35.64/1.25 ms; FOV = 260x260 mm^2; Matrix = 256x256; Slice Thickness = 0.8cm; and in-plane spatial resolution was 1mm x 1mm. As part of the clinical examination, gadolinium-DTPA (0.2mmol/kg) was infused via an indwelling intravenous catheter at an average rate of 4mL/s. After 15 minutes, LGE images were acquired using an inversion recovery pulse sequence (FOV same as bSSFP; Matrix = 256x192; TR/TE = 796/3.28ms; Averages = 1; Flip Angle = 25°, TI =250-350ms for optimal nulling). Healthy volunteers did not receive gadolinium. All data analysis was performed in Matlab (Mathworks, Nattick, MA). For data acquired in patients receiving gadolinium, an SCMR level II reader identified a region of non-enhanced myocardium on LGE images, and myocardial regions with signal intensity greater than 2 standard deviations above the mean were classified as enhanced at LGE. In healthy controls and patients not demonstrating enhancement at LGE, the maximum change in myocardial signal (ΔS) was calculated by normalizing the difference between the peak systolic signal intensity and the myocardial signal at end-diastole to the myocardial signal at end-diastole. In patients demonstrating enhancement at LGE, ΔS was calculated separately for non-enhanced and enhanced myocardium. In addition, the time to peak signal was determined for all patients. Longitudinal shortening was measured in ImageJ from 4 chamber cine bSSFP images. Peak longitudinal shortening was calculated as distance from the left ventricular apex to the mitral valve. For analysis, data was divided into 4 groups: healthy control (Group 1), patients who did not demonstrate enhancement at LGE (Group 2), non-enhanced tissue from patients with enhancement at LGE (Group 3), and enhanced tissue from corresponding patients (Group 4). A continuation-ratio logit model was fit in R using peak ΔS and ΔL as inputs. One slice from each patient was analyzed. For comparison of time to peak measurements, a one-way ANOVA test was performed in Matlab. **Results**: The logit model revealed a discriminative capacity between healthy controls and the remaining patients (Figure A,B). While peak ΔS does not appear to be different between enhanced and non-enhanced tissue in patients demonstrating enhancement at LGE, the time to peak signal change was significantly higher in enhanced myocardium (Figure C). **Discussion**: Our results suggest that further analysis of signal dynamics in routinely acquired cine bSSFP CMR images could enable identification of edematous and fibrotic myocardium without the need for additional LGE imaging. We examined only 1 slice in each patient, many of whom demonstrated enhancement at LGE in other slices, thus potentially causing a wider distribution of data in these patients. More comprehensive whole-heart examination may provide higher discriminative power. **Conclusion:** Combined analysis of bSSFP signal waveforms and longitudinal shortening can potentially enable rapid and non-invasive tissue characterization. **Acknowledgements:** National Center for Advancing Translational Sciences grant number KL2TR000116 and NIH CTSA UL1TR000117, and AHA14CRP20380071. **References: (1)** Zhou X et al. MRM.2011;66:187-191. **(2)** Kumar A et al. JACC.2011;4(12):1936-878. **(3)** Goldfarb et al. JMRI.2011;33:573-581.

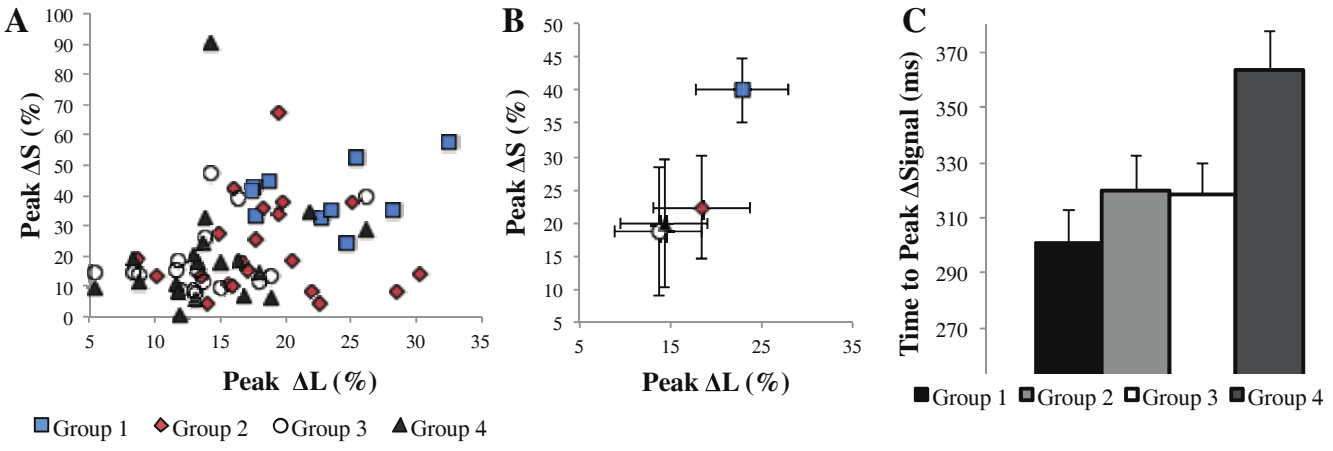

Figure. **A**. Association of peak longitudinal shortening and peak change in myocardial signal intensity reveals different patterns between healthy controls (group 1), patients who did not demonstrate LGE enhancement in the imaged slice (group 2), and patients who demonstrated enhancement in the imaged slice (groups 3 and 4). **B.** Mean and standard deviation over all data. **C.** Time to peak signal change is significantly elevated in tissue that enhances at LGE (group 4) compared to all other tissues ($p<0.05$ via ANOVA).