Respiratory Self-Gated 2D Cine Balanced SSFP Myocardial Edema Imaging: Preliminary Study in Canines

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Introduction: A number of different approaches, including balanced steady-state free precession (bSSFP), have been proposed for the identification of myocardial edema that ensue acute myocardial infarction. One of the appealing features of bSSFP imaging approach is that functional, as well myocardial edema information, can be acquired within the same scan. To date, 2D cine bSSFP based myocardial edema imaging has been prescribed with multiple breatholds to cover the entire left ventricle. To reduce patient discomfort, particularly in the setting of acute myocardial infarction, it is highly desirable if these acquisitions can be prescribed without suspending respiration. In this work, we investigate the utility of respiratory self-gated 2D cine bSSFP myocardial edema imaging in a canine model subjected to ischemia-reperfusion injury.

Methods: Animal Preparation & imaging: Canines (n = 3) were operated on using procedures and protocols approved by our institution. A left thorocotomy was performed in dogs and a hydraulic occluder was secured around the left anterior descending coronary artery (LAD) for inflicting no-flow ischemia. Following a week of recovery, ischemia reperfusion injury was imposed with a no-flow ischemia (3 hours), followed by 2 hours of reperfusion. All MRI studies were performed using a 1.5 T Espree system (Siemens Healthcare, Germany) using the body coil for excitation and cardiac and spine array coils for signal reception. Studies were performed 2 hours and 48 hours post reperfusion. Breath-held and free-breathing bSSFP acquisitions were prescribed in the short axis orientation. The presence of infarct was confirmed with late enhancement MRI. Scan parameter for bSSFP MRI: TR/TE=3.5/1.7ms, Flip angle=70°, BW=930Hz/pixel, spatial resolution=1.25X1.25X8.0mm^3; and segments per cardiac phase = 8. Breath-held scans were acquired within 10-15 seconds. Free-breathing scans were acquired with 5 repeated measurements with the same acquisition parameters, along with an additional centre k-space (respiratory self gating) line that was acquired at the end of each cardiac phase. Reconstruction of Respiratory Self-Gated (RSG) Cine bSSFP Images: Reconstruction of free-breathing bSSFP images were performed offline in MATLAB (Mathworks, USA). Using the self-gating lines, centre-of-mass values were computed as previously described [1]. The end-expiration phase was identified and an acceptance window of approximately 1.5-4.00 mm was chosen. Once a sufficient number of phase-encoding lines were accepted, 2DFT of the data was performed. It was found that with 5 measurements, it was always possible to reconstruct free-breathing bSSFP cine images. Data Analysis: Breath-held and RSG bSSFP images were loaded into ImageJ (NIH, USA) and end-diastolic images were identified on the basis of trigger times. Regions of interest (ROI), hyperintense area within the LAD territory and remote (healthy) area (confirmed on the basis of late enhancement MRI), were drawn on the breath-held bSSFP images and were copied onto RSG bSSFP images. The mean signal intensities within the ROIs, drawn on breath-held and RSG bSSFP images, were measured and the edema contrast, defined as the percent signal difference between the hyperintense and remote zones, normalized by the signal intensity of the remote zone, was computed. A paired t-test was used to test the difference in myocardial edema contrast in breath-held and RSG bSSFP images. A linear regression analysis was also performed between myocardial edema contrast values computed from breath-held and RSG-bSSFP images. Statistical significance was set at $p<0.01$.

Results: Myocardial edema was visualized as hyperintense zones in the anterior wall (LAD territory) in breath-held and RSG bSSFP images (Fig. 1) throughout the cardiac cycle, albeit cardiac motion related artifacts were observed in few cardiac phases. Average edema contrast in breath-held and RSG images (Mean±SD) were 46.99±19.59 and 55.14±21.96, respectively. Paired t-test showed that there was no statistical difference between the edema contrast computed from breath-held and RSG images. Linear regression (Fig. 2) showed a strong correlation between edema contrast computed from breath-held and RSG-bSSFP images; correlation coefficient, R = 0.95 with fit parameters, intercept 5.1±8.7 and slope 1.07±0.17, with $p<0.01$.

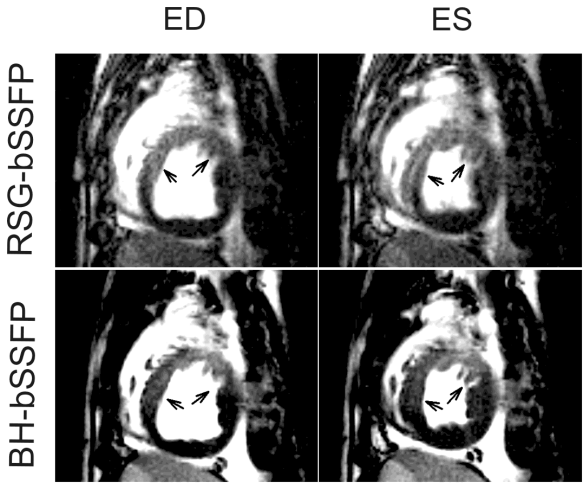

Fig. 1 Representative end diastolic (ED) and end systolic (ES) breath-held (BH) and RSG bSSFP images.

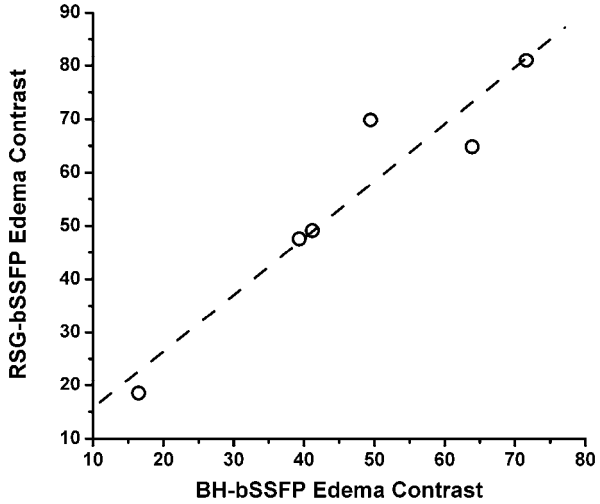

Fig. 2 Scatter plot showing the correlation between breath-held (BH) and RSG bSSFP edema contrast. The dashed line is the line of best fit between BH- and RSG-based bSSFP edema contrast.

Discussion & Conclusion:
Early results show that RSG bSSFP imaging is capable of generating edema contrast similar to breath-held bSSFP imaging. Optimization strategies to reduce scan time and correction of cardiac motion artifacts remains to be investigated.

References: [1] Crowe ME *et al* MRM 2004.