Use of deformable registration for quantification of cardiac perfusion in patients with arrhythmia
Devavrat Likhite¹, Ganesh Adluru¹, Chris J. McGann², and Edward DiBella¹
¹UCAIR/Radiology, University of Utah, Salt Lake City, Utah, United States ²Cardiology, University of Utah, Salt Lake City, Utah, United States

Introduction: The use of DCE MRI in quantification of myocardial blood flow is gaining clinical credence. Generally an ECG–gated sequence is used to acquire 3-5 short axis slices spanning the heart from the base to the apex. However this creates a problem in patients with arrhythmia wherein the irregular heartbeats lead to missed triggers. More generally, gating can be a problem, especially at high field strengths. Recently a new concept of ungated acquisition and retrospective self-gating was used for quantifying perfusion [1]. Here we compare self-gated perfusion approach directly with a gated acquisition to study the effectiveness of an ungated acquisition and self-gating combined with deformable registration for the estimation of myocardial blood flow.

Methods: Radial perfusion data was acquired on a Siemens 3T Verio scanner using a radial saturation recovery turboFLASH sequence in 7 volunteers in sinus rhythm at rest. The acquisition parameters were 20-24 rays per image, TR=2.2ms, TE=1.2ms, 2.3x2.3x10mm voxels. Four to five slices were acquired after a single saturation pulse with a delay of ~50ms. Gadoteridol 0.05mmol/kg was injected and ~230 frames were acquired over a minute with no gating and breath hold or shallow breathing. The same sequence was used with gating. Prior to each of the ungated and gated acquisitions, dilute (10%) volume matched acquisitions were performed to obtain the unsaturated arterial input functions (AIFs) [2].

Images were reconstructed using a spatio-temporally constrained reconstruction (STCR) method [3]. After reconstruction, the initial step of self-gating [1] involved automatic detection of the LV-RV position and summing the signal intensity around the LV to cluster the timeframe into systolic or diastolic based on a peak or a trough. Figure 1 shows an example of finding the location of the left ventricle (LV) and the region used to create Figure 2. Figure 2 shows the plot of the sum in the region. Peaks are classified as diastolic timeframes and troughs as systolic. ~40-50% of the timeframes are used. Figure 3 shows the images binned into systole and diastole for two datasets. Model-based deformable registration is employed to suppress the residual cardiac motion. Further processing involves automatic image segmentation and extraction of the 6 azimuthal region blood curves per slice. The precontrast value was subtracted off from each tissue curve. Slight manual shifts were performed in some datasets to account for breathing motion. Figure 4 shows the tissue curves from a single region with and without the use of model based deformable registration. The data was fit to a two compartment model and the $K^\text{trans}$ was reported. The same processing steps except the initial self gating and deformable registration were performed on the gated datasets.

Results/Discussion: Figure 5 compares the perfusion values obtained from gated acquisition versus those obtained from self-gated (diastole). The results from the different subjects are color coded. Correlation of 0.8 between the gated and self-gated (diastole) acquisition and 0.77 between gated and self-gated (systole) was obtained. The correlation between the $K^\text{trans}$ from gated versus self-gated was much lower when the deformable registration was not used ($r=0.45$ for diastole and $r=0.51$) for systole). Figure 6 shows the Bland-Altman plot between the $K^\text{trans}$ from gated and ungated acquisition showing that the self-gated approach with the use of deformable registration gave similar quantitative perfusion estimates compared to a gated acquisition. A standard deviation of 0.25 was observed in the Bland-Altman plot compared to a standard deviation of 0.54 without the use of deformable registration. This work shows that the use of deformable registration with self-gating may enable useful quantification of cardiac perfusion. Further studies and assessment of the repeatability of the methods are needed.