Use of deformable registration for quantification of cardiac perfusion in patients with arrhythmia

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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].

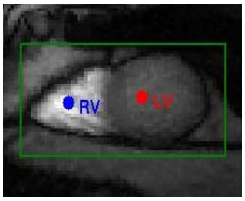

Figure 1: Example of detecting LV position.

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^{trans} was reported. The same processing steps except the initial self gating and deformable registration were performed on the gated datasets.

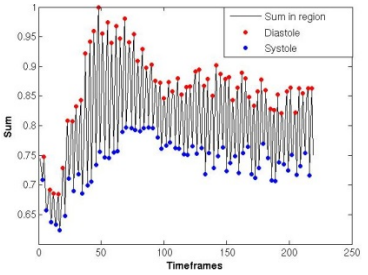

Figure 2: Binning of timeframes into systole or diastole depending on the sum in the region

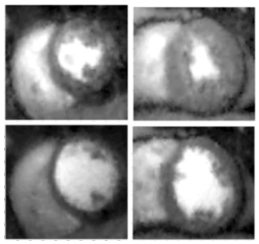

Figure 3: The first row shows the systolic timeframe for two datasets and the second row shows the corresponding diastolic timeframe.

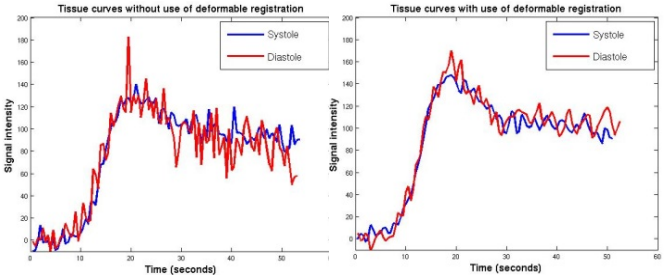

Figure 4: Left: Tissue curves without use of deformable registration. Right: Tissue curves using deformable registration

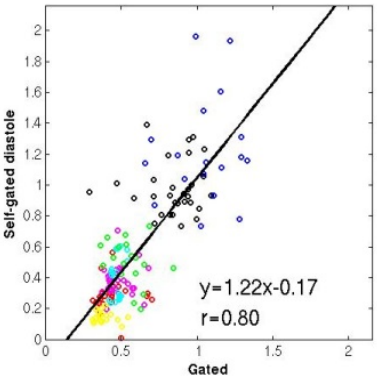

Figure 5: Regression of self-gated K^{trans} and the gated K^{trans}. Subjects are grouped by color.

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^{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^{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.

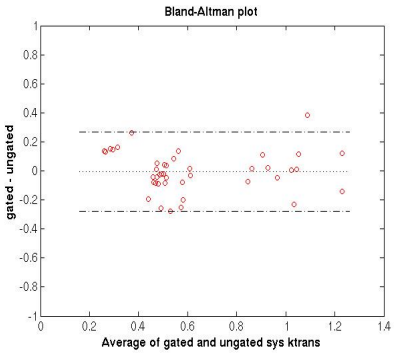

Figure 6: Bland Altman plot of gated and ungated K^{trans} after use of deformable registration

References: [1] DiBella et al. #157, ISMRM 2012. [2] M. Ishida et al. JCMR 13:28, 2011. [3] Adluru et al. 29:466-473, JMRI 2009