Comparison of Quantitative Myocardial Perfusion from Self-gated and Gated Acquisitions

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Introduction: Dynamic contrast enhanced MRI for characterizing perfusion in the myocardium is becoming a more robust and useful clinical tool. A new concept of ungated acquisitions and retrospective self-gating was recently introduced [1]. Such ungated imaging could be valuable whenever ECG-gating is poor, and in particular in patients with arrhythmias. In fact, some perfusion works reject datasets without a sinus rhythm. Here we compare a self-gated perfusion acquisition directly to a gated acquisition in subjects in sinus rhythm, to determine how well quantitative perfusion values in ml/min/g can be obtained with the self-gated approach.

Methods: A saturation recovery radial turboFLASH sequence was used in four subjects in sinus rhythm (age=58±12, two female) at rest to directly compare gated and ungated quantitative cardiac perfusion imaging. TR/TE=2.2/1.2msec, FOV=260mm, 2.3x2.3x10mm pixel size on a 3T Verio (Siemens) scanner. 20-24 rays in a golden ratio order were acquired for each slice. Four or five slices were acquired after a single saturation pulse and a ~50 msec delay. Each image was acquired in 42-53msec and repeated every ~250msec with no gating and during breath-hold or shallow breathing. Gadoteridol 0.05mmol/kg was injected and ~230 sets of slices were acquired over a total of a minute. Thus each slice was acquired at various cardiac phases in each heartbeat. The same sequence was also used with ECG gating. The order of the acquisitions was random, with approximately 15 minutes between the gated and ungated acquisitions. Dilute (10%) volume-matched injections were acquired in the first part of each ungated and gated acquisition as in [2] to provide unsaturated AIFs.

Reconstruction and Processing: First, the images were reconstructed with an iterative compressed sensing method [3]. Fig. 1 shows an example. Further processing was performed for the ungated images - the RV was found automatically and a region of interest around the heart was selected. The sum in the selected area was used as the retrospective navigator to bin the data into systole or diastole. Not all of the data was binned. Local peaks of the curve were selected by locations where the signal's first difference in time changed sign from positive to negative.

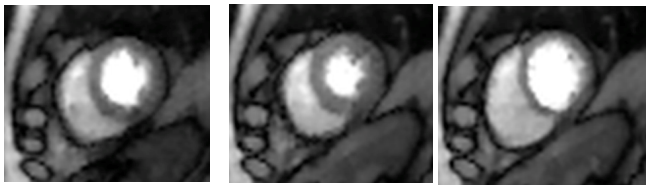

Figure 1: Left: Gated acquisition, one time frame as tissue enhances (one slice out of 10). Middle and right: An ungated acquisition was done 15 min. later and two adjacent time frames - near systole and near diastole are shown (one slice out of 5). Image quality is comparable for the gated and ungated images.

Both datasets were then processed with our standard methods of automated image registration and segmentation, followed by manual adjustments and selection of LV borders. Time curves from 6 azimuthal regions per slice were generated and the pre-contrast value subtracted off. Fig. 2 shows an example of mean tissue time curves from one slice in a gated and ungated study.

A basal diastolic slice was chosen to provide the AIF for all of the slices in that acquisition. The low concentration dual-bolus curve scaled up by 10 was used for the AIF. To compensate for differences in SRT and coil sensitivity between slices, the non-AIF slices were scaled so that the tails of the tissue time curves summed to the same values in each slice. Processing for the gated and ungated datasets was done independently. The curves were fit to a compartment model and the K^{trans} parameters reported.

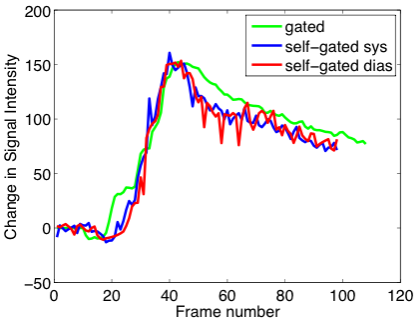

Figure 2: Tissue time curves, mean in one slice. The gated and the self-gated systolic and diastolic curves appear similar. More variation is seen in the self-gated data.

Results/Discussion: Fig. 3 compares the perfusion parameters estimated from the gated and from the diastolic self-gated dataset. Fig. 4 shows the relation with the systolic self-gated and gated data, albeit in a different manner. The systolic and diastolic values correlated y=1.2x-0.27, r=0.86. The self-gating method had more variation in the time curves due to cardiac motion and the self-gating process (Fig. 2). However, K^{trans} correlated well between the two methods.

A limitation is the small dataset size and the difficulty of interpreting regression analysis on data that is scatter around a mean flow (resting perfusion is relatively uniform). However, the results are very promising given that an automatic self-gated procedure was used, without any manual intervention and without non-rigid registration. We expect improved results with the use of non-rigid registration to align the frames that are all near systole or near diastole. Including the registration within the reconstruction will likely yield further gains.

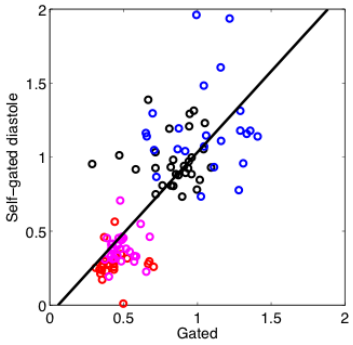

Figure 3: Regression of self-gated diastolic perfusion parameters with gated parameters. The points are color-coded by volunteer. y=1.1x-0.06, r=0.77

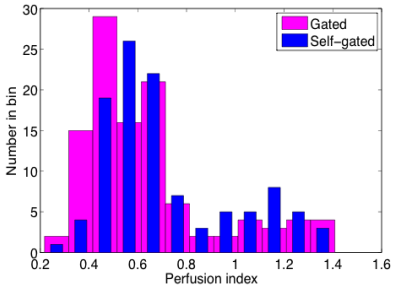

Figure 4: Histogram comparison of self-gated systolic perfusion compared to gated parameters. 4 subjects, 4-5 slices each (108 total regions). It is expected that flows at rest mostly reflect scatter about a mean, this is an alternate way to view the data compared to Fig. 3. The regression is y=0.73x+0.3, r=0.73. The distributions are similar.

The studies here show that the self-gated approach has promise for obtaining quantitative perfusion values. This could be particularly useful for studying longitudinal changes in patients with arrhythmias. The approach could also be useful more generally since gating can be an Achilles heel in particular at high field strengths. Also, the study of perfusion differences at systole and diastole could be valuable [4] and is possible with this method. Further studies are needed to better determine the accuracy of the technique.

References: [1]E. DiBella, et al., ISMRM, 222, 2011. [2] M. Ishida et al. JCMR 13:28, 2011. [3] G. Adluru et al., JMRI 29:466-73, 2009. [4] A. Radjenovic et al. MRM 64:1616-24.