Cardiac Diffusion-Weighted MRI with Selective RF Excitation in a Single Breath-Hold

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TARGET AUDIENCE: Physicists and clinicians interested in cardiac magnetic resonance (CMR) imaging and diffusion-weighted imaging (DWI).

PURPOSE: Improved myocardial tissue characterization using CMR is highly desirable across a wide range of ischemic and non-ischemic heart diseases. Diffusion-weighted imaging (DWI) is widely used in in the early detection of stroke and other neurological diseases, but its application in CMR has been challenging due to motion-induced signal loss. ***The purpose of this work*** was to investigate the feasibility of acquiring cardiac DWI with multiple b-values during a single breath-hold exam.

METHODS:

<u>*MRI Pulse Sequence:*</u> Images were acquired on a 3T system using an 8-channel cardiac array coil (Discovery MR750, GE Healthcare, Waukesha, WI). A two-dimensional, echo-planar reduced field of view (rFOV) radiofrequency (RF) pulse was used to selectively excite the heart. Fat signal was suppressed using the chemical shift in rFOV excitation k-space combined with a slice-selective refocusing pulse[1]. Other parameters included rFOV = 22 cm × 13.2 cm, matrix size = 64 × 64, corresponding to a true in-plane resolution of 3.4 mm × 2.1 mm, slice thickness = 8 mm, number of slices = 4, TR = 2 RR-interval, TE = 58 ms, number of averages per b-value = 2, scan time 28 RR-interval.

<u>*Cardiac Triggering:*</u> Diffusion preparation was performed at a single, optimal trigger delay (TD) at the most quiescent period of the cardiac cycle. The optimal TD was determined with an automatic script using a series of routine cine bSSFP short-axis images. The difference image between different cine images was used as a measure for the amount of cardiac motion at a given trigger delay (TD). Entropies of the difference images were calculated, and the cardiac phase with the maximum difference image entropy was selected as the most quiescent frame. This cardiac phase has the "least meaningful" difference with the succeeding cardiac phase and can be assumed to correspond to the least moving portion of the cardiac cycle. Diffusion encoding was performed in a single direction near the optimal TD and was followed by a single-shot EPI readout.

<u>*Human Subjects:*</u> Five healthy subjects were recruited after informed consent was obtained in accordance with our institutional review board (IRB) guidelines.

<u>*Model Fitting:*</u> A two-compartment, bi-exponential model was fitted to the data (b-value = 10-500 s/mm2) to estimate fast and slow perfusion and diffusion components, respectively[2]. ADC maps were generated using a mono-exponential fit on only the slow diffusion components (b-value = 200-500 s/mm^2).

RESULTS: ***Figure 1*** shows changes of difference image entropy over the cardiac cycle obtained from short-axis cine bSSFP images from a healthy volunteer (M, 34yo). Maximum entropy occurs at a TD of 630 ms corresponding to 62% of cardiac cycle for a heart rate = 59. ***Figure 2*** shows DW images and the ADC map from the same subject acquired about the optimal trigger delay. Left and right ventricles are visible at both lower and higher b-values.

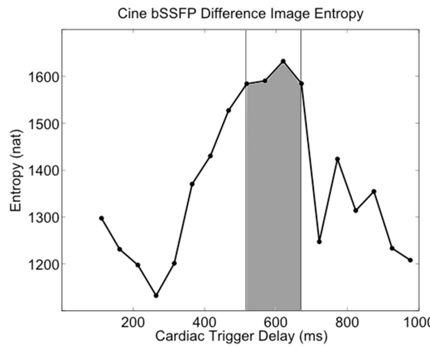

FIG1. Entropy of the difference image from a series of cine images is maximized during mid-diastole period (gray area) showing suitable trigger delay range for diffusion encoding.

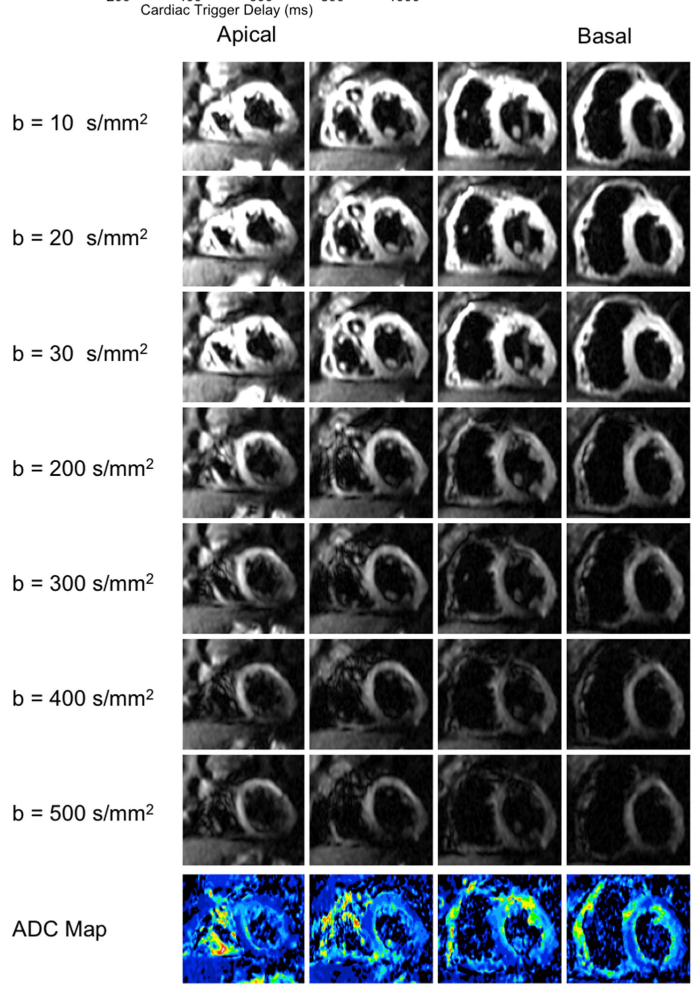

FIG2. Full cardiac coverage is achieved with 7 different b-values in a single breath-hold. ADC map can be generated using the 4 higher b-values to limit the contributions of fast diffusing components. Note the higher diffusivity in the right ventricular wall compared to the left ventricle.

DISCUSSION AND CONCLUSION: Motion-induced signal loss in Cardiac DWI can be minimized when the diffusion preparation corresponds to the quiescent phase of the cardiac cycle. The optimal TD varies across individuals and is heart rate dependent. Information content of cine images can be used to identify the quiestent period of the cardiac cycle to select the optimal TD. Small matrix size in rFOV imaging leads to minimized EPI distortions. Further, fat suppression can be achieved without any extra saturation pulses. DWI acquisition at both low and high b-values coupled with a bi-exponential fit can be used to estimate perfusion and diffusion in myocardium. **ACKNOWLEDGMENTS:** Funding for this work was provided by NIH R21-HL121977 grant.

REFERENCES: [1] Saritas et al. MRM 2008;60:468-473 [2] Le Bihan et al. Radiol. 1988;168:497-505