In Vivo Diffusion-Weighted MRI: Contrast-Free Detection of Myocardial Fibrosis in Hypertrophic Cardiomyopathy Patients

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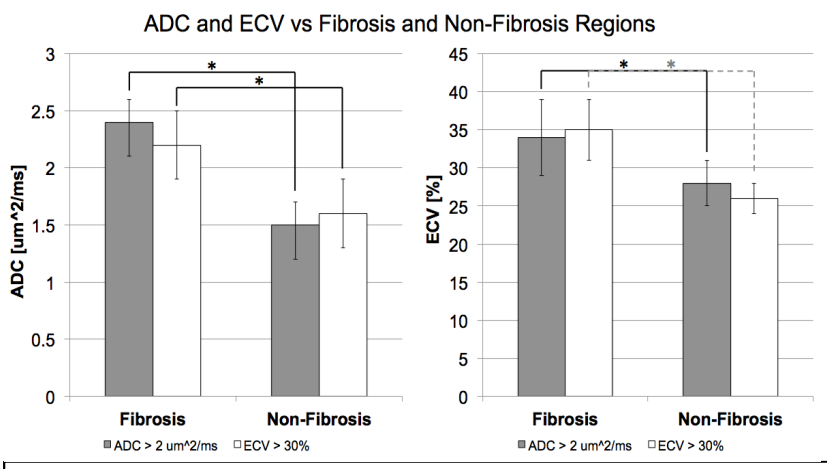
Target Audience – MR scientists, MR engineers, Cardiologists, and Radiologists specializing in cardiac imaging

Introduction – Recent studies have demonstrated the potential of in vivo diffusion-weighted MRI (DWI) in detecting myocardial replacement fibrosis for chronic myocardial infarction [1-3]. Despite the potential of this contrast-free technique, detecting diffuse myocardial fibrosis with DWI has not been established. Current cardiac MRI (CMR) techniques to detect diffuse myocardial fibrosis include late gadolinium enhancement (LGE) [4], pre/post contrast T1 mapping [5], and extracellular volume (ECV) mapping [6]. We propose the application of a recently developed cardiac DWI technique [7] to detect diffuse myocardial fibrosis in HCM patients and compare its performance with established CMR techniques.



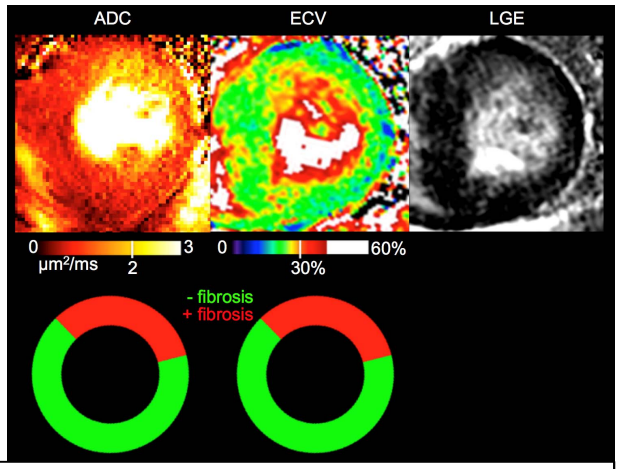
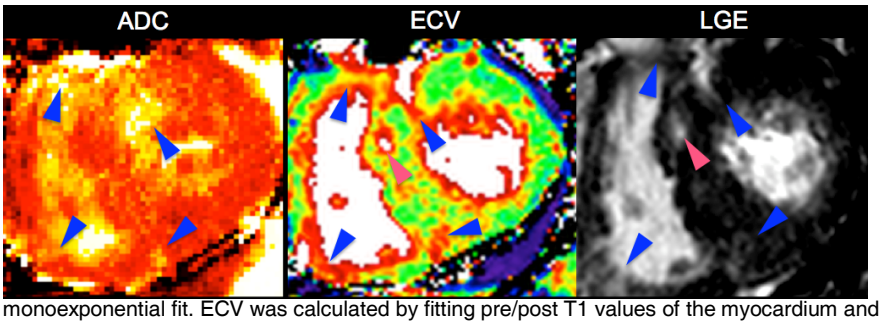


Figure 1 (left) – ADC and ECV in fibrosis and non-fibrosis regions defined by either ADC > 2 um^2/ms or ECV > 30% were compared. Both ADC and ECV were significantly ($p < 0.01$) higher in fibrosis than non-fibrosis regions for both criteria. **Figure 2 (right)** – Representative example of ADC and ECV maps with associated AHA wheels. LGE is provided for reference. Qualitatively, the ADC and ECV maps are in agreement with matching endocardial presentation of fibrosis in the anterior and anteriolateral AHA segments. This is further substantiated quantitatively with excellent agreement in the AHA wheels. **Figure 3 (bottom)** – Representative example showing concordance among ADC, ECV, and LGE on the AHA regional level (blue arrows), but shows disagreement within the anteroseptal AHA region (pink arrows) between ECV/LGE and ADC.



Methods – HCM patients (N = 23) were recruited and consented under Institutional Review Board. All patients were scanned on a 1.5T Siemens Avanto with the following protocol: standard morphological localizers, DWI (3 orthogonal diffusion directions, b = 350 s/mm^2, free breathing), pre/post contrast T1 mapping (MOLLI, TI_{min} = 100ms, TI_{inc} = 80msec, breath-hold), and standard phase sensitive inversion recovery late gadolinium enhanced (LGE). LGE was provided as a clinical reference to contextualize the qualitative presentation of ADC and ECV maps. LGE was not used in the quantitative comparisons to evaluate diffuse fibrosis. ADC was calculated using a monoexponential fit. ECV was calculated by fitting pre/post T1 values of the myocardium and blood pool with a collected hematocrit percentage [6]. All images were acquired in the short axis view with matching slice positions. ADC and ECV images were segmented into 6 American Heart Association (AHA) segments. Positive regions for myocardial fibrosis were defined as: ADC > 2.0 μm^2/ms [1] and ECV > 30% [8]. For ADC and ECV, a two-sample t-test was performed to evaluate the difference between mean values of fibrotic and non-fibrotic regions. To test for agreement in regional detection, Cohen's Kappa test was performed along with calculating sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) using ECV as the gold-standard reference.

Results – ADC of fibrotic regions (2.4 ± 0.2 μm^2/ms) was significantly ($p<0.01$) higher than ADC of non-fibrotic regions (1.5 ± 0.2 μm^2/ms) (Fig 1, 2). Similarly, ECV of fibrotic regions (35 ± 4%) was significantly ($p<0.01$) higher than ECV of non-fibrotic regions (26 ± 2%). In fibrotic regions defined by ECV, ADC (2.2 ± 0.3 μm^2/ms) was again significantly ($p< 0.05$) higher than ADC of non-fibrotic regions (1.6 ± 0.3 μm^2/ms). In fibrotic regions defined by ADC criterion, ECV (34 ± 5%) was significantly ($p < 0.01$) higher than ECV in non-fibrotic regions (28 ± 3%). Regional detection between ADC and ECV of diffuse fibrosis yielded substantial agreement ($\kappa = 0.66$) with high sensitivity, specificity, PPV, NPV, and accuracy (0.80, 0.85, 0.81, 0.85, and 0.83, respectively). Qualitatively, LGE, ADC, and ECV presented similarly on the AHA regional level, but subtle textural differences existed within some regions (Figure 3). Additionally, the similar presentation can also be seen in the right ventricle (anterior and inferolateral).

Conclusion – Cardiac DWI is sensitive to diffuse myocardial fibrosis and is capable of characterizing the extent of fibrosis in HCM patients.

References – [1] Nguyen, et al. JCMR 2014 [2] Pop, et al. PMB 2013 [3] Wu, et al. MRM 2007 [4] Moravsky, et al. JACC 2013 [5] Moon, et al. JCMR 2013 [6] Kellman, et al. JCMR 2012 [7] Nguyen, et al MRM. 2013 [8] Kellman, et al. JCMR 2012