In Vivo Cardiac DTI on a Widely-Available Clinical Scanner

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

Introduction – Currently, there are only two main methods to perform cardiac diffusion tensor imaging (DTI) that either rely on the subject exhibiting stable, periodic RR cycle (stimulated echo acquisition mode methods [1]) or utilize specialized research scanners that have ultra-high gradient strengths (spin-echo [2]). Recent work has demonstrated that gradient moment nulling (GMN) of the second order (M0,M1,M2: up to constant acceleration) with a diffusion preparation spin echo scheme is capable of yielding robust diffusion weighted images (DWI) [3]. To extend this work, we present a preliminary novel cardiac DTI sequence that utilizes a diffusion preparation scheme that maintains M1,M2 GMN while being robust to imperfect B1 refocusing that is expected at high main fields (≥3T). We compare this with no GMN compensation (M0 only) and first order compensation (M0,M1: up to constant velocity).

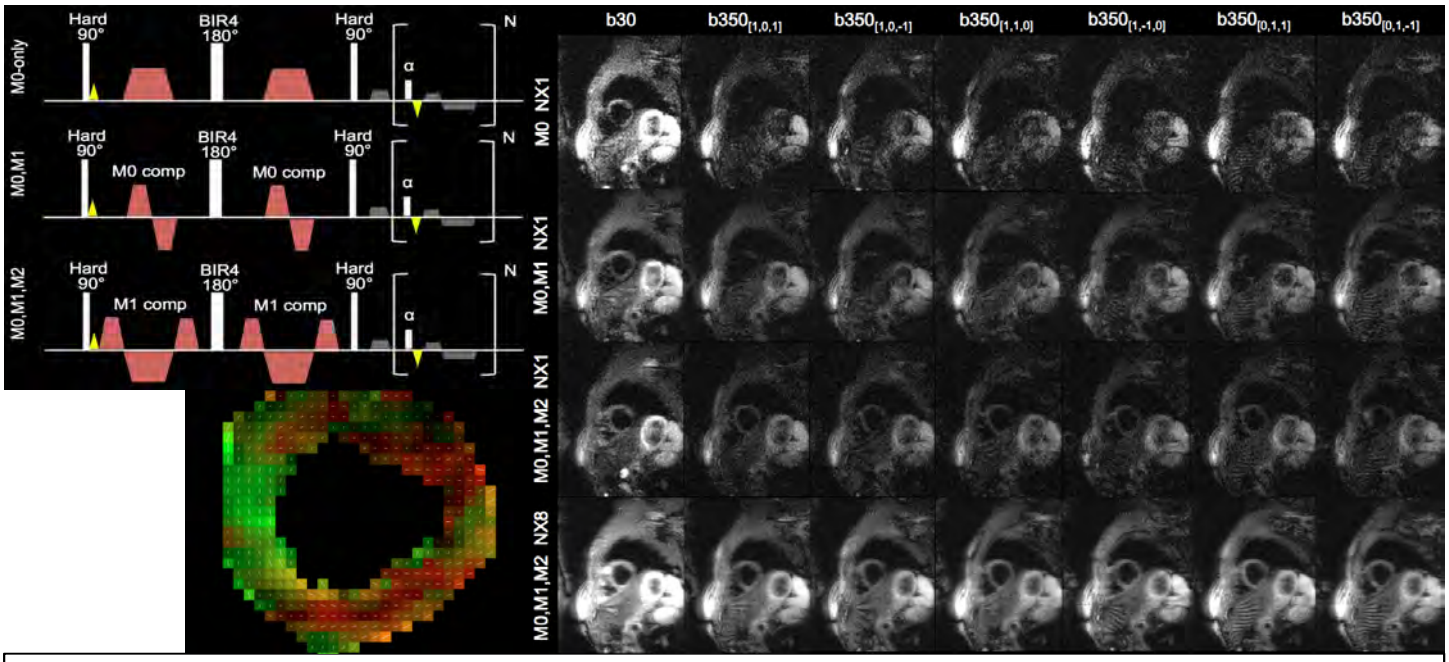

Figure 1 (left) – Pulse sequence diagram of the three diffusion prepared pulses preceding a GRE readout. BIR4 was used as the single refocusing pulse a pair of crushers reduced T1 contamination and phase-related errors . **Figure 2 (right)** – Representative example of raw diffusion weighted images of the M0-only, M0,M1 compensated, and M0,M1,M2 compensated DTI. No visible signal loss was displayed in the M0,M1,M2. **Figure 3 (bottom left)** – Representative example of the in-plane fiber orientation map derived from the M0,M1,M2 DTI data. Fiber orientation in the lateral wall is affected due to possible B1 inhomogeneity.

Methods – Three healthy subjects were recruited and consented under Institutional Review Board. All subjects were scanned on a 3.0T Siemens Verio with the following protocol: standard morphological localizers and 3 DTI scans (1 b30 + 6 non-collinear diffusion directions b = 350 s/mm^2, free breathing prospective navigator gating, GRE readout, 2.7x2.7x8mm^3, flip angle = 20°, single-shot, parallel imaging factor = 2) utilizing M0 only compensation (TEprep = 35ms), M0,M1 compensation (TEprep = 46ms), and M0,M1,M2 compensation (TEprep = 75ms). Acquisition was carried out during the quiescent period of diastole. Gradient amplitudes were set to 60.8 mT/m (two 43 mT/m max gradients simultaneously on). The pulse sequence diagrams (Fig 1) show that a common single BIR4 refocusing pulse [4] and a set of crusher gradients [5] to minimize T1 contamination and phase-related errors (eddy currents) are used. DTI reconstruction utilized custom software developed in Python using the DIPY library [6] to generate mean diffusivity, fractional anisotropy, and in-plane primary eigenvector orientations.

Results – A vast majority (93% across all subjects) of DWIs generated from M0-only DTI scans displayed complete signal fallout (Fig 2 row 1). For M0,M1 DTI scans, DWIs did not display any complete signal fallout, but instead partial signal loss was observed (Fig 2 row 2. For M0,M1,M2 DTI scans, no signal loss was visibly detected in any of the DWIs (Fig 2 row 3) and excellent signal-to-noise ratio was achieved with 8 averages (Fig 2 row 4). Qualitatively, color anisotropy whisker plot (Fig 3) of the M0,M1,M2 DTI data showed fiber orientation consistent with previous literature [1, 2] of normal human subjects. The effect of B1 inhomogeneity was still visible in fiber orientation maps, which was seen in the lateral wall of all 3 subjects.

Conclusion – A novel cardiac DTI technique was preliminarily performed on a widely used clinical 3T scanner and yielded fiber orientation maps that were mostly consistent with previous literature. Technical improvements are still needed to improve lateral wall B1 inhomogeneity.

References – [1] Nielles-Vallespin, et al. MRM 2013 [2] Gamper, et al. MRM 2003 [3] Nguyen, et al. MRM 2014 [4] Garwood, et al. JMR 1991 [5] Lin, et al. MRM 2008 [6] Brett, et al. HBM 2011.