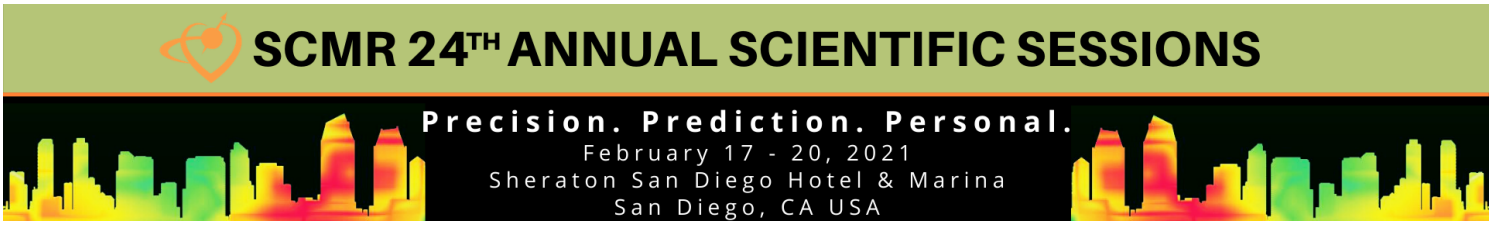

Submission Title: The Effects of Motion Compensated Encoding Waveforms in Cardiac Diffusion Tensor Imaging: A Moving Phantom Study

SUBMISSION PREVIEW: THE EFFECTS OF MOTION COMPENSATED ENCODING WAVEFORMS IN CARDIAC DIFFUSION TENSOR IMAGING: A MOVING PHANTOM STUDY

The Effects of Motion Compensated Encoding Waveforms in Cardiac Diffusion Tensor Imaging: A Moving Phantom Study

Submission ID: **943259**

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GE Healthcare

Part 1
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Part 2
I Agree

Abstract

Topic

Contrast Agents and Novel Contrast Mechanisms

Format Type

- Scientific Sessions or SCMR/ISMRM Co-Provided Workshop

Presentation Type

- Oral Presentation or Traditional Poster

Background

Recent developments in diffusion gradient waveform design enables *in vivo* cardiac Diffusion Tensor Imaging (cDTI) as a feasible and reliable approach[1-3]. Exploration of cDTI has proven to be a useful clinical tool to assess several types of cardiomyopathies[4-9]. Spin-echo approaches use high-order motion compensation that increases the echo time (TE) and thus the temporal footprint of diffusion encoding. Although the efficacy of motion compensated diffusion encoding strategies have been demonstrated *in silico*[10] and *in vivo*[1-3], it remains unclear how residual motion affects the accuracy of the diffusion measurement. The ***objective*** of this work was to evaluate the accuracy and precision of quantitative tensor invariants with various motion compensated diffusion encoding strategies using a programmable linear motion stage.

Methods

An isotropic agar phantom was connected to a programable MRI compatible linear motion stage (Shelley Medical) programmed and triggered to simulate cardiac motion with a sinusoidal motion trajectory (±5mm, 1000ms R-R).

Imaging was performed at 3T (Skyra, Siemens) using a 32-channel array. Images were acquired with and

without programmed motion at one slice location using a custom spin-echo EPI cDTI sequence (b-values: 0, 350s/mm^2; 6 directions; 1.5 x 1.5 x 5.0mm^3; 5 averages; TR=1000ms) with different orders of motion compensation (position moment nulling: M_0, velocity moment nulling: M_1, acceleration moment nulling: M_2) for which the TEs were 82, 115, and 112ms, respectively.

cDTI was measured at three time points spanning a mix of velocities and accelerations (Fig. 1). Motion compensation with and without programmed motion was compared using mean diffusivity (MD) and fraction of anisotropy (FA).

Results

Fig. 2 shows DWI, MD, and FA maps with and without programmed motion. Fig. 3 shows MD and FA plots for the M_0, M_0+M_1, and M_0+M_1+M_2 sequences for the static phantom and three moving timepoints. In the presence of motion, the M_0 and M_0+M_1+M_2 sequences show a change in the mean MD value and an increased standard deviation, with respect to the static data. MD values measured with the M_0+M_1 sequence were most similar to the static phantom at the three imaging times. FA values were expected to be ~0 (isotropic phantom) and the measurements show a small change across all sequences.

Conclusion

Moment nulling, as previously shown, is an efficient way to mitigate cardiac motion in cDTI acquisitions. However, these controlled experiments indicate that higher moment nulling does not always correlate with more accurate quantitative results when imaged under the same conditions. Additional experiments that: emphasize encoding motion around the refocusing pulse; test different encoding durations; evaluate more combinations of acceleration and velocity; and include deformation are required for more insight on the effects of residual moments due to motion.

Uploaded File(s)

Images

Figure 1. Position (top left), velocity, (middle left), and acceleration (bottom left) curves of the 1D programmable linear motion stages shown with the corresponding start time for each sequence. Inset plots show the separation of sequence start times for M0 (red), M1 (green) and M2 (blue) which each sharing the same center of k-space acquisition to acquire slices in the same exact location. The pulse sequence diagrams for for M0 (top right), M1 (middle right), and M2 (bottom right) show the diffusion footprint and TEs for each. It should be noted that on the M1 sequence, crushers (labeled C and colored orange) are required.
Effects_of_MoCo_cDTI_Figure_1.pdf

Figure 2. Example acquisition from the M2 nulled sequence acquired at Time Point 2 both without (top row) and with motion (bottom). From left to right, the images are: non-diffusion weighted, diffusion weighted, Mean Diffusivity (MD) maps, and Fraction of Anisotropy (FA) maps.
Effects_of_MoCo_cDTI_Figure_2.pdf

Figure 3. Quantitative box and whisker plots for Mean Diffusivity (top) and Fractional Anisotropy (bottom). Baseline timepoints, labeled as Static, are compared with moving Time Point 1 (minimum absolute velocity and maximum absolute acceleration), moving Time Point 2 (non-zero velocity and non-zero acceleration), and moving Time Point 3 (maximum absolute velocity and minimum absolute acceleration) for different orders of motion compensation (M0, M1, and M2). M1 motion compensation shows stable MD and FA across all timepoints with respect to the Static phantom.
Effects_of_MoCo_cDTI_Figure_3.pdf

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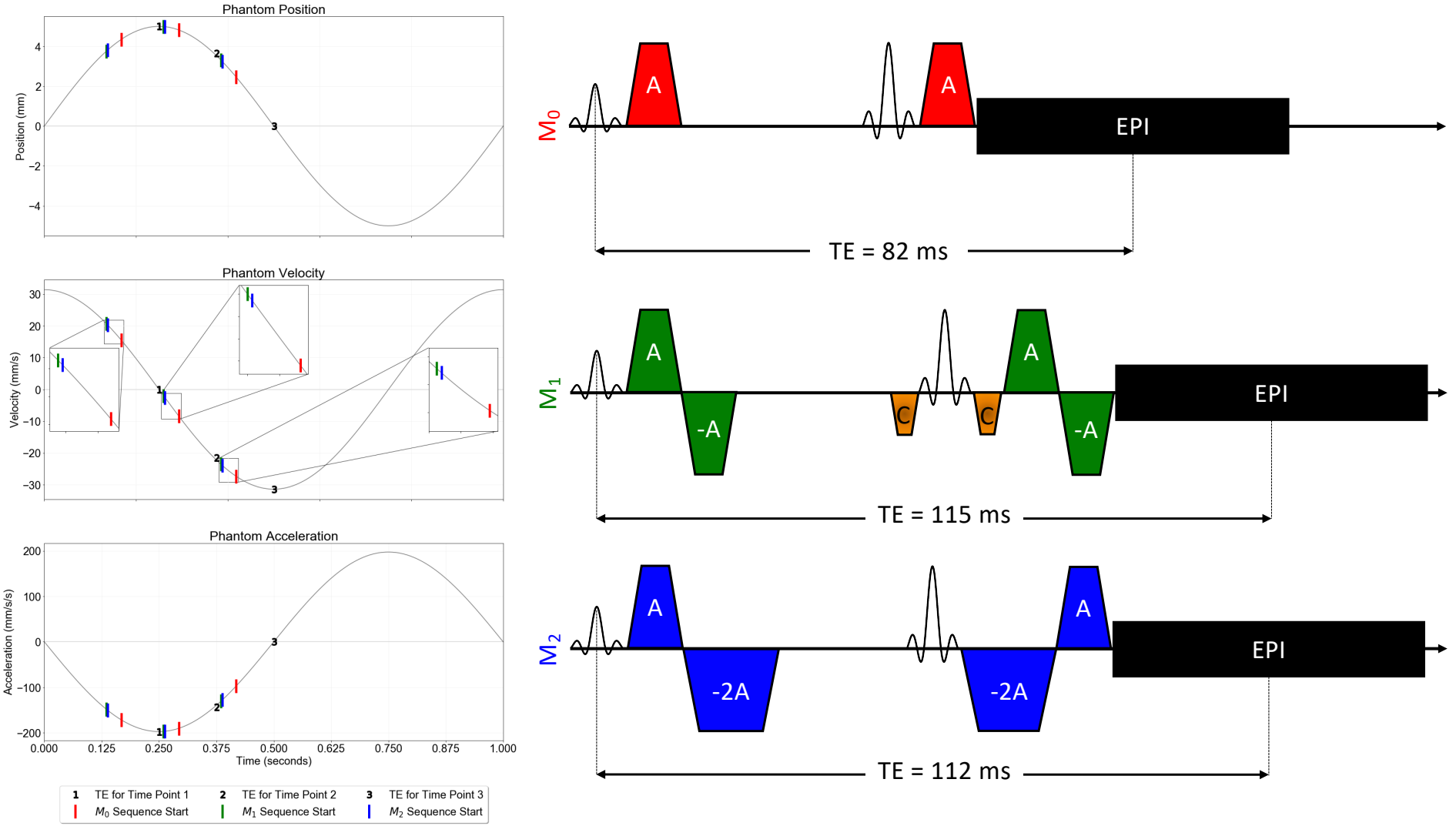
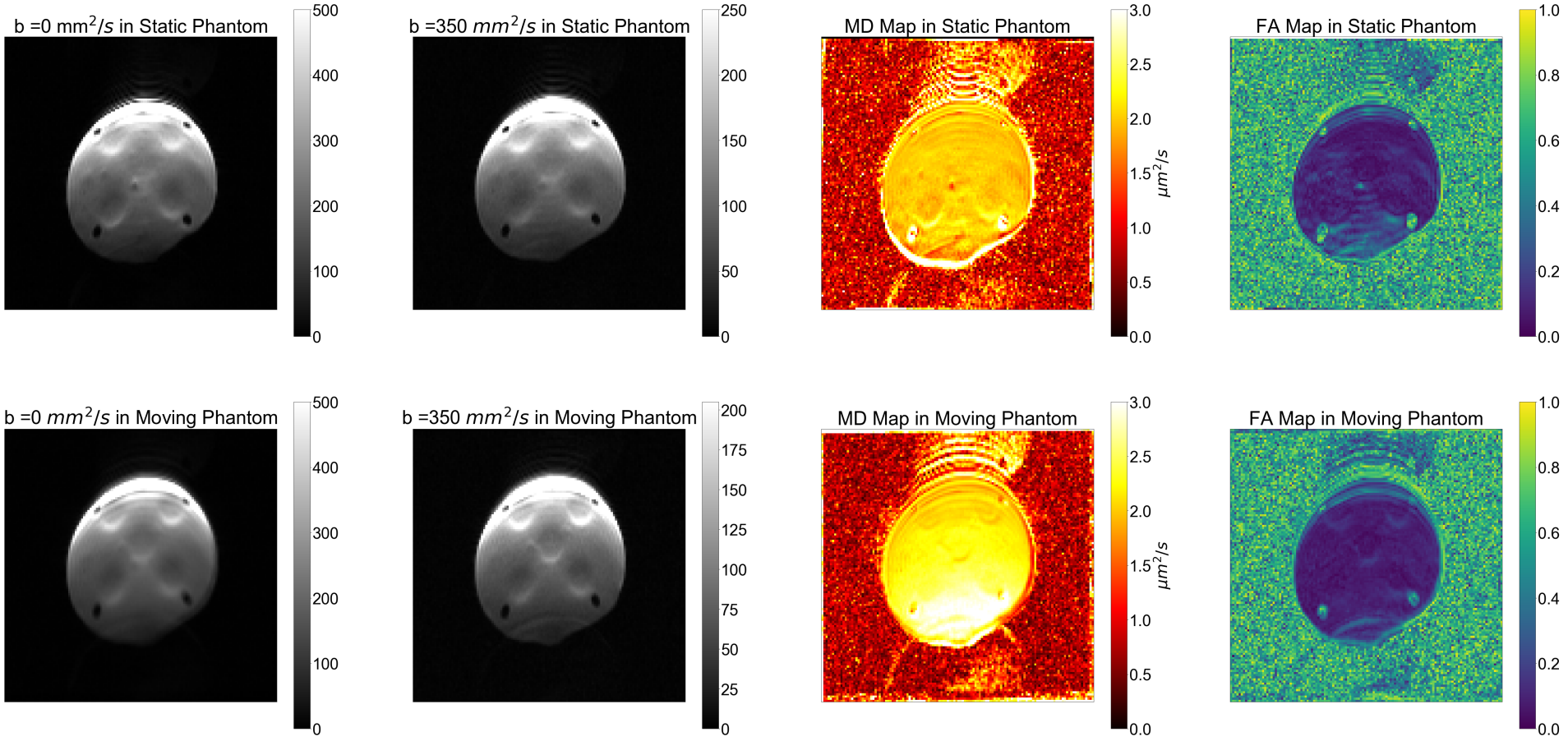
Keywords

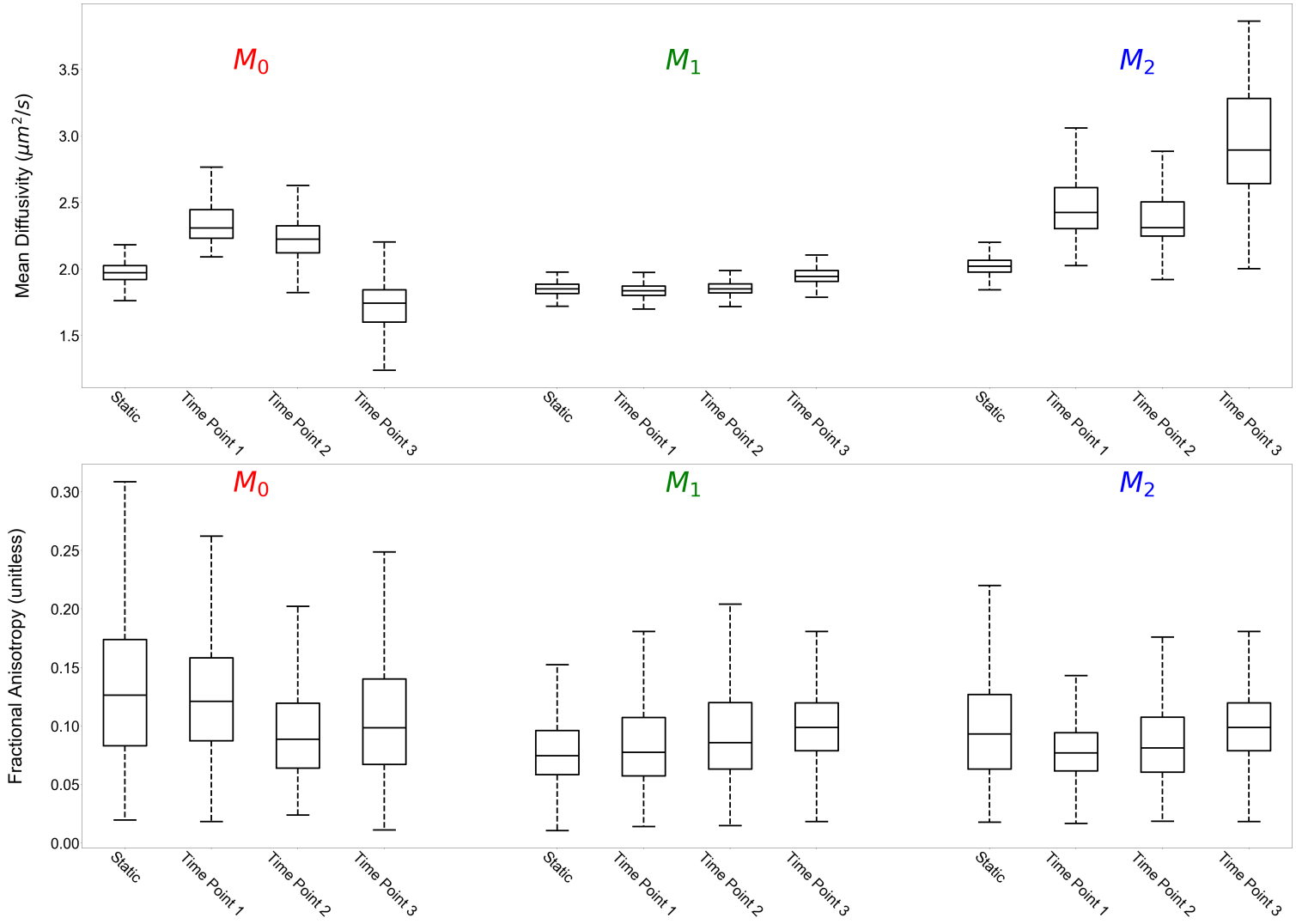
Keyword One:
Diffusion Weighted Imaging

Keyword Two:
Motion Correction

Keyword Three:
Pulse Sequences


Phantom Position
Position (mm)
Phantom Velocity
Velocity (mm/s)
Phantom Acceleration
Acceleration (mm/s/s)
Time (seconds)
1 TE for Time Point 1
2 TE for Time Point 2
3 TE for Time Point 3
M_0 Sequence Start
M_1 Sequence Start
M_2 Sequence Start
M_0
A
A
EPI
TE = 82 ms
M_1
A
-A
C
C
A
-A
EPI
TE = 115 ms
M_2
A
-2A
-2A
A
EPI
TE = 112 ms


b =0 mm^2/s in Static Phantom
500
400
300
200
100
0
b =350 mm^2/s in Static Phantom
250
200
150
100
50
0
MD Map in Static Phantom
3.0
2.5
2.0
1.5
1.0
0.5
0.0
$\mu m^2/s$
FA Map in Static Phantom
1.0
0.8
0.6
0.4
0.2
0.0
b =0 mm^2/s in Moving Phantom
500
400
300
200
100
0
b =350 mm^2/s in Moving Phantom
200
175
150
125
100
75
50
25
0
MD Map in Moving Phantom
3.0
2.5
2.0
1.5
1.0
0.5
0.0
$\mu m^2/s$
FA Map in Moving Phantom
1.0
0.8
0.6
0.4
0.2
0.0


M_0
M_1
M_2
Mean Diffusivity ($\mu m^2/s$)
3.5
3.0
2.5
2.0
1.5
Static
Time Point 1
Time Point 2
Time Point 3
Fractional Anisotropy (unitless)
0.30
0.25
0.20
0.15
0.10
0.05
0.00