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

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Declaration of Financial Interests or Relationships

Speaker: Tyler Cork

I have no financial interests or relationships to disclose with regards to the subject matter of this presentation.

Cardiac Diffusion Tensor Imaging

Spin Echo DTI

- 1 heartbeat
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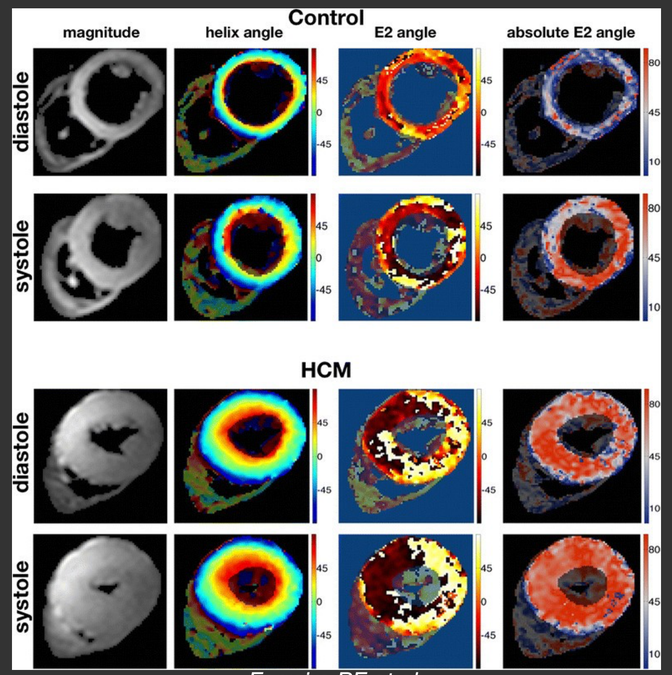
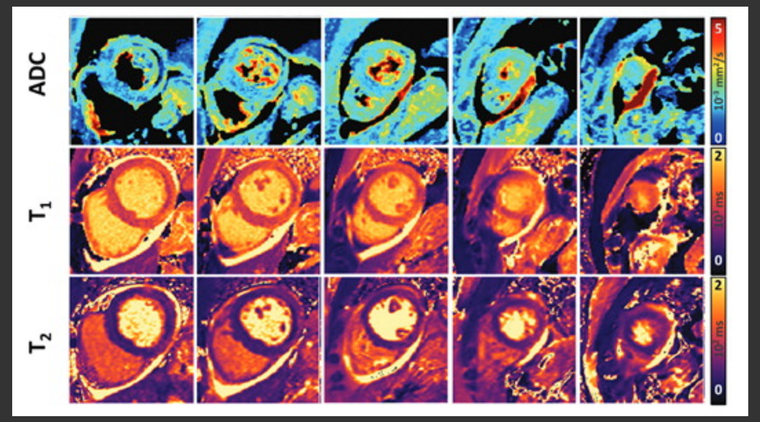
Clinical Applications

- Hypertrophic cardiomyopathy [1-3]
- Chronic myocardial infarction [4]
- Acute myocardial infarction [5]



Ferreira PF et al.
Journal of Cardiovascular Magnetic Resonance.
2014;16:87.



Moulin K et al. Radiology. 2020;293

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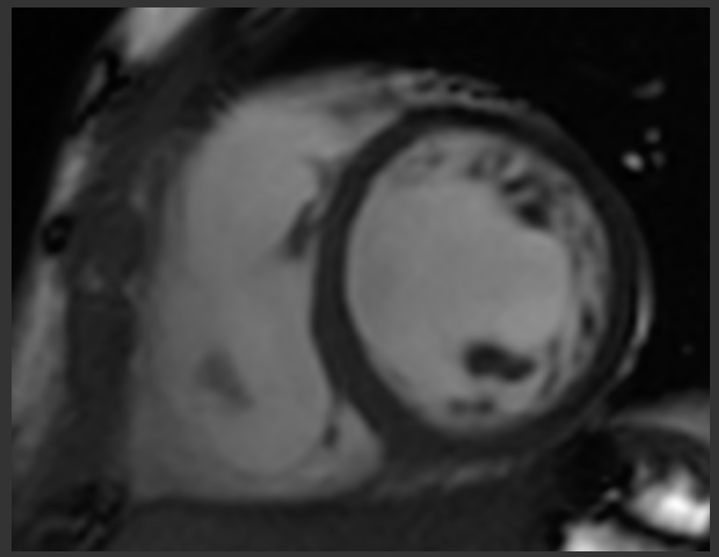
5. Moulin K et al. Radiology. 2020;293

Cardiac Motion and cDTI

Types of Cardiac Motion

- In-plane motion
  - Intra-voxel dephasing
  - Tissue deformation

In-Plane Motion



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- Through-plane motion
  - Slice movement

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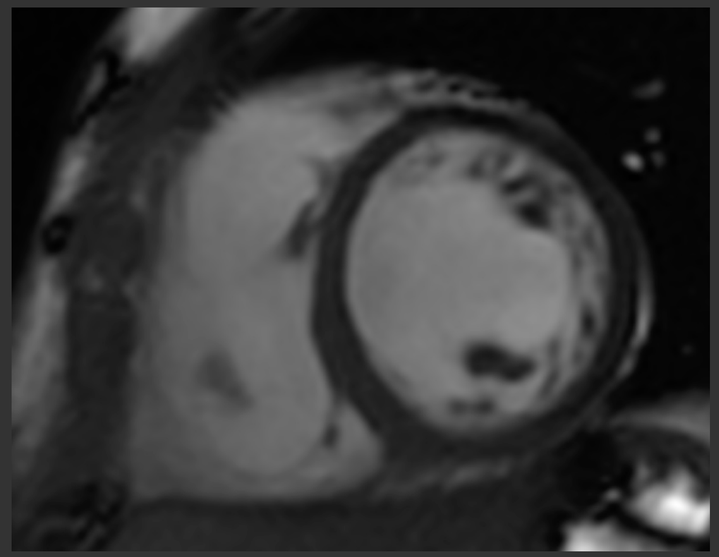
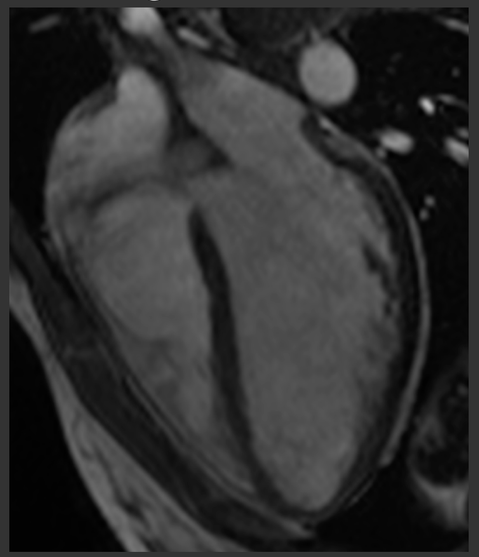


Through-Plane Motion



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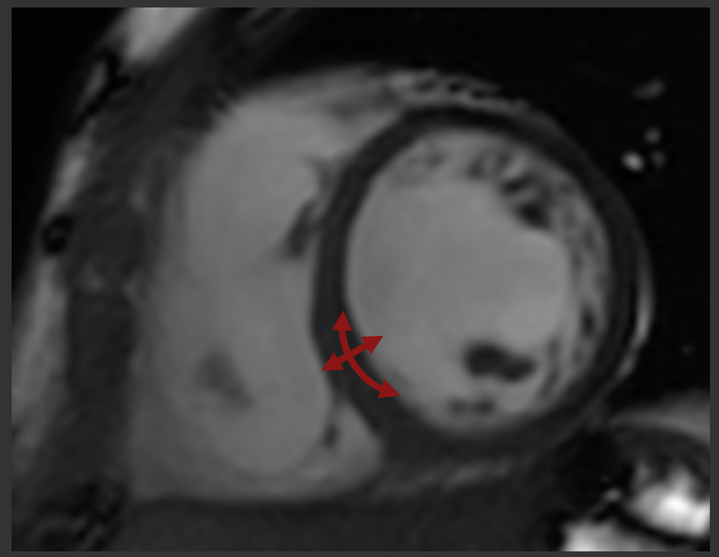
Accounting for Motion in cDTI

- Motion compensation gradient waveforms [6-9]
  - Position Compensated: M_0
  - Velocity Compensated: M_1
  - Acceleration Compensated: M_2

In-Plane Motion



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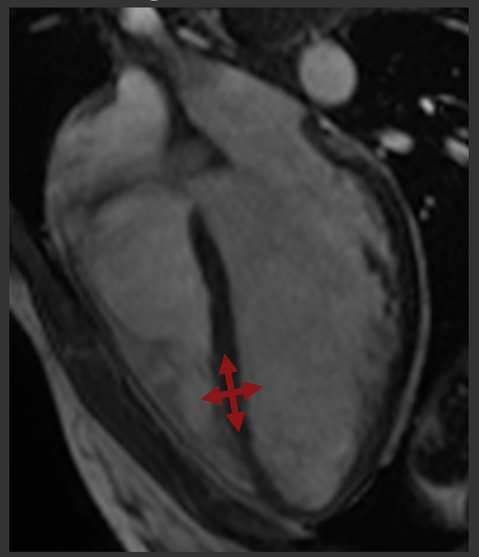

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Objective

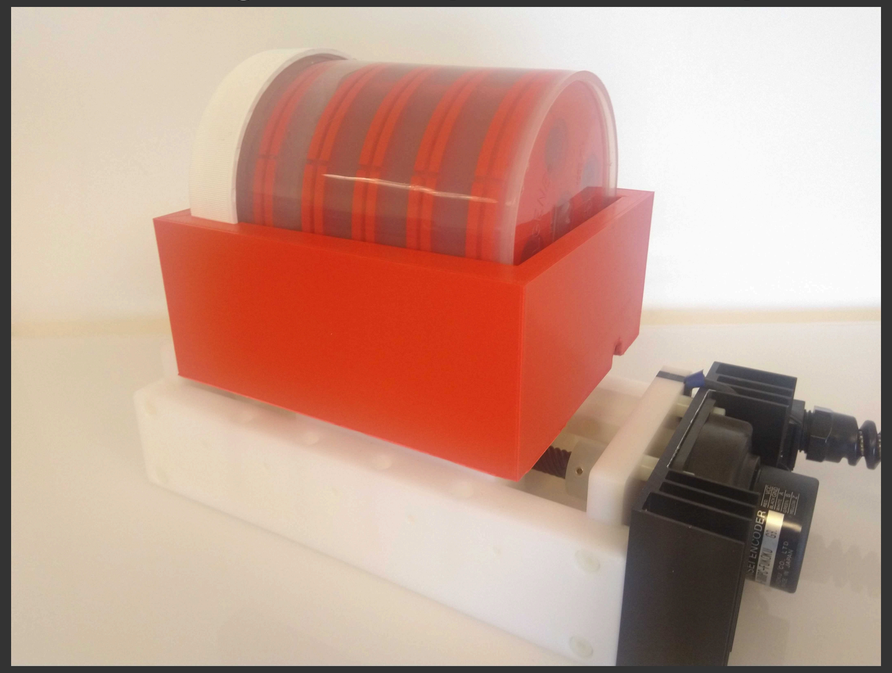
Evaluate the effects of through-plane motion for various motion compensated diffusion encoding strategies.

Experimental Set Up

Phantom Setup

- Structured isotropic agar phantom

Through-Plane Experimental Set up



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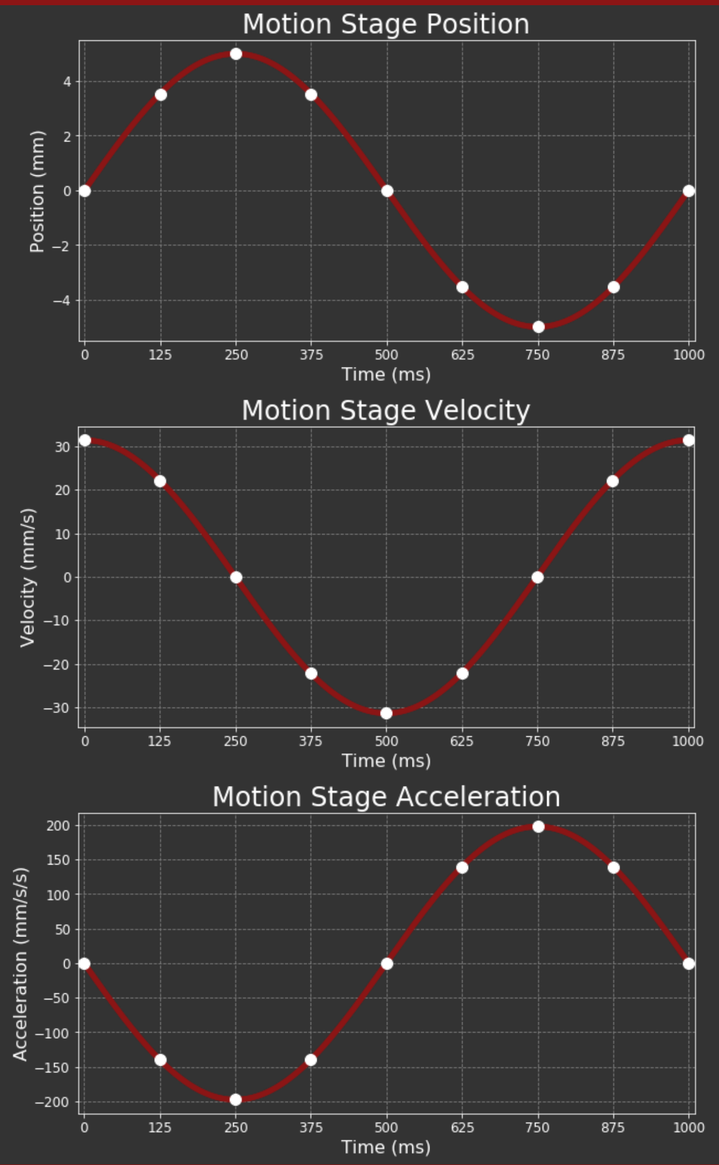
Programable Linear Motion Stage

- Stationary acquisition
- $y = 5\,mm \cdot \sin(\frac{2 \cdot \pi \cdot t}{1000\,ms})$
  - 10 mm peak-to-peak displacement
  - 1000 ms R-R interval
- 8 time points with programmed motion
  - 125 ms delays between each timepoint

Timepoint (ms)	Position (mm)	Velocity (mm/s)	Acceleration (mm/s/s)
0	0	31.4	0
125	3.5	22.2	-139.6
250	5.0	0	-197.4
375	3.5	-22.2	-139.6
500	0	-31.4	0
625	-3.5	-22.2	139.6
750	-5.0	0	197.4
875	-3.5	22.2	139.6
1000	0	31.4	0



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Imaging Parameters

- Hardware
  - 3T Siemens Skyra
  - 32 channel chest and spine coil

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- Spin-echo EPI DTI
  - b-values: 0 s/mm^2 and 350 s/mm^2
  - Number of diffusion directions: 6
  - Voxel resolution: 2.0 x 2.0 x 5.0 mm^3
  - Number of averages: 5
  - Full Fourier k-space acquisition
  - TR: 1000 ms

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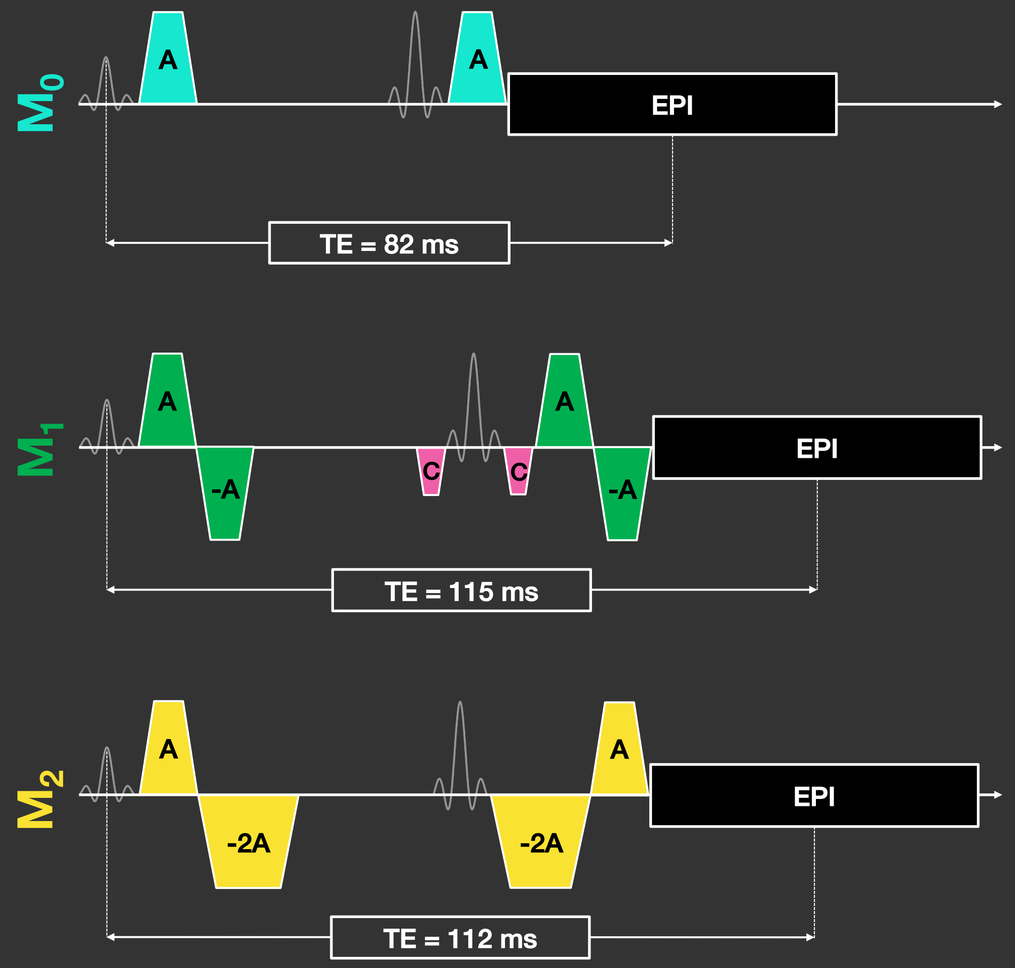
  - TE of motion encoding schemes:
    - Position moment nulling (M_0): 82 ms
    - Velocity moment nulling (M_1): 115 ms
    - Acceleration moment nulling (M_2): 112 ms



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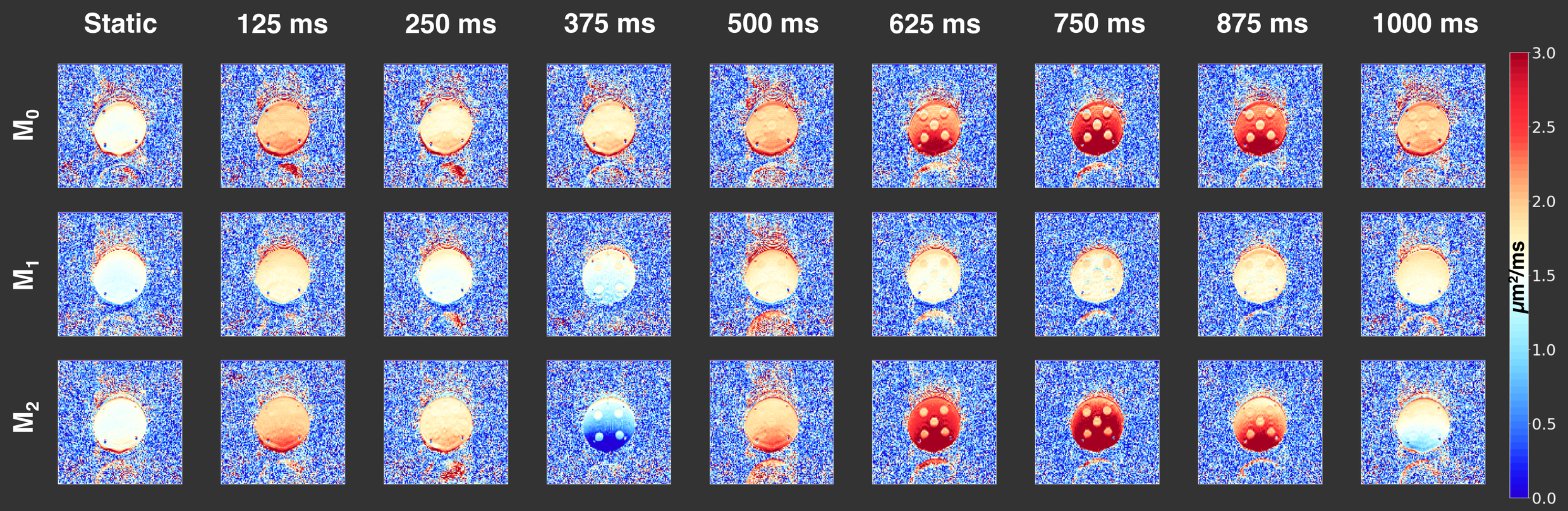
  - Sequence Synchronization schemes
    a) 90° excitation pulses synchronized
    b) 180° refocusing pulses synchronized
    c) TE synchronized

Results

Mean Diffusivity: 90° Excitation Pulses Synchronized



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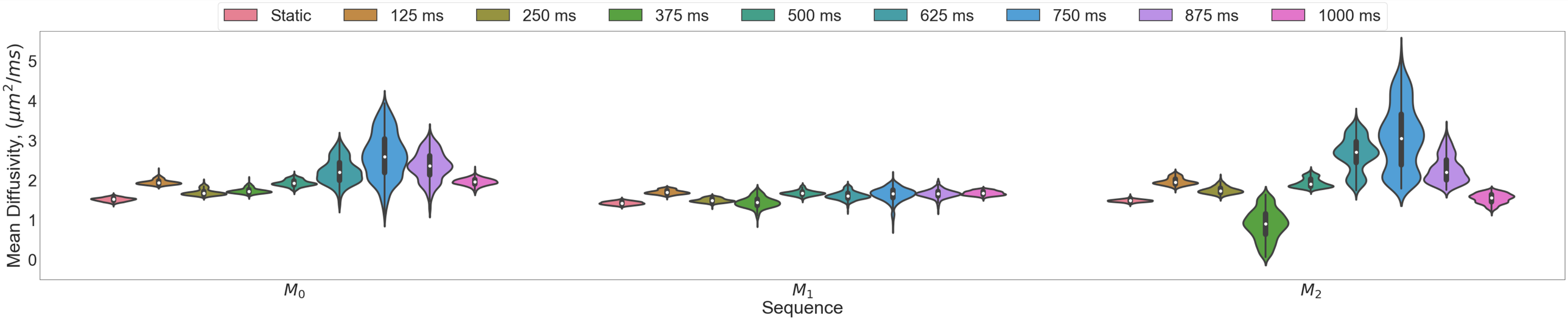
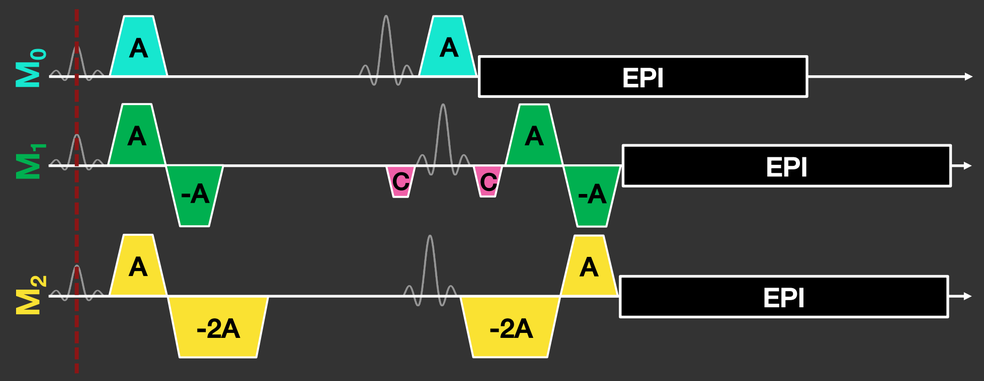
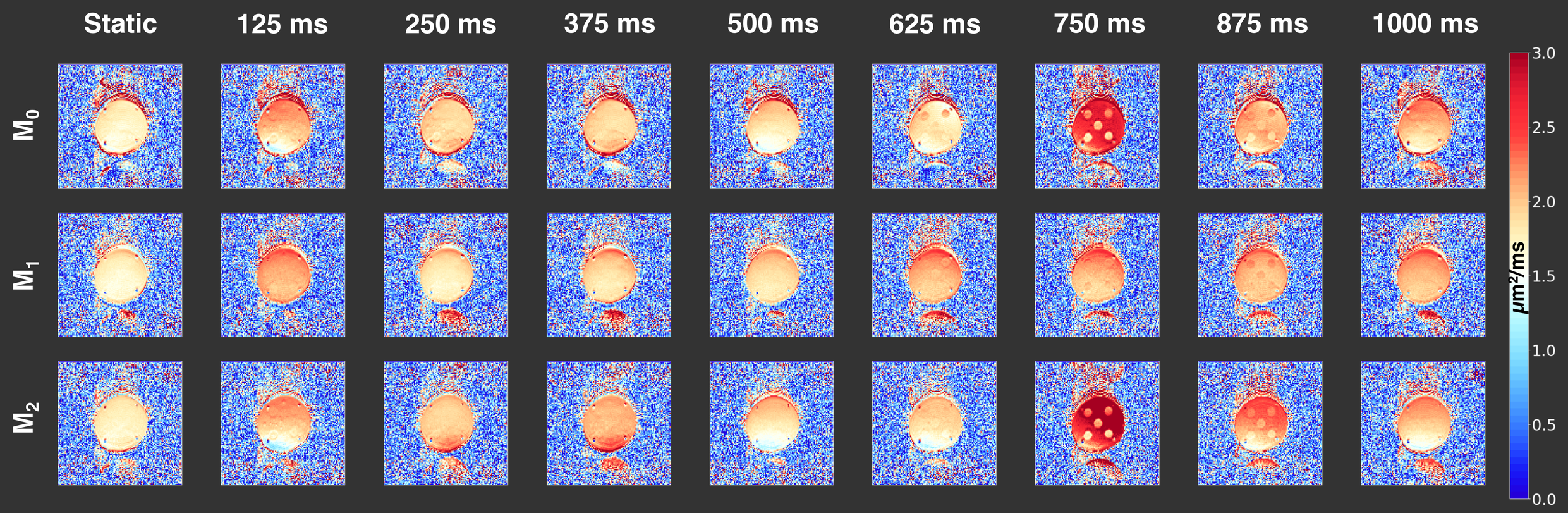




Results

Mean Diffusivity: 180° Refocusing Pulses Synchronized



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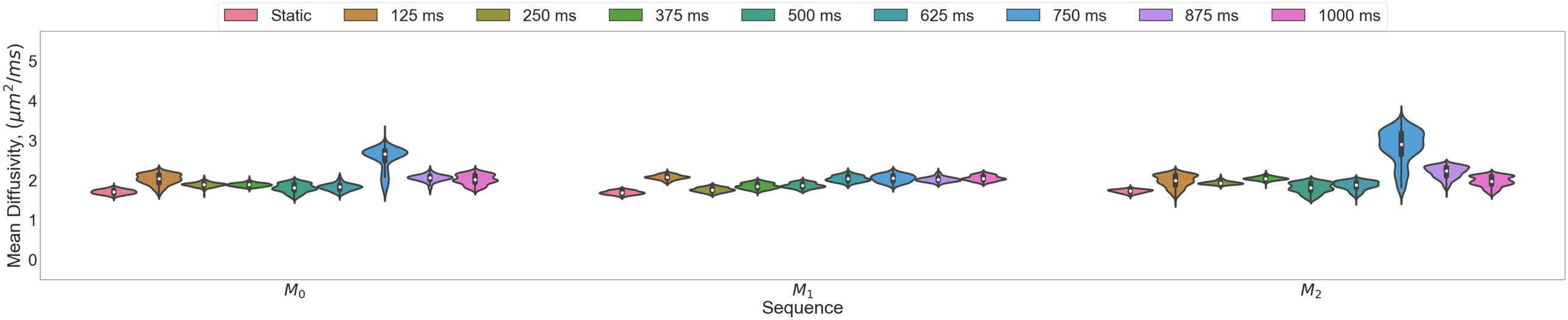

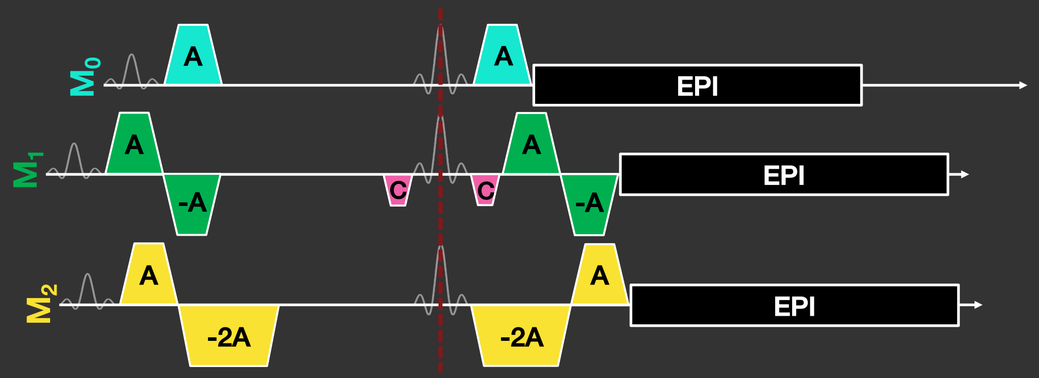

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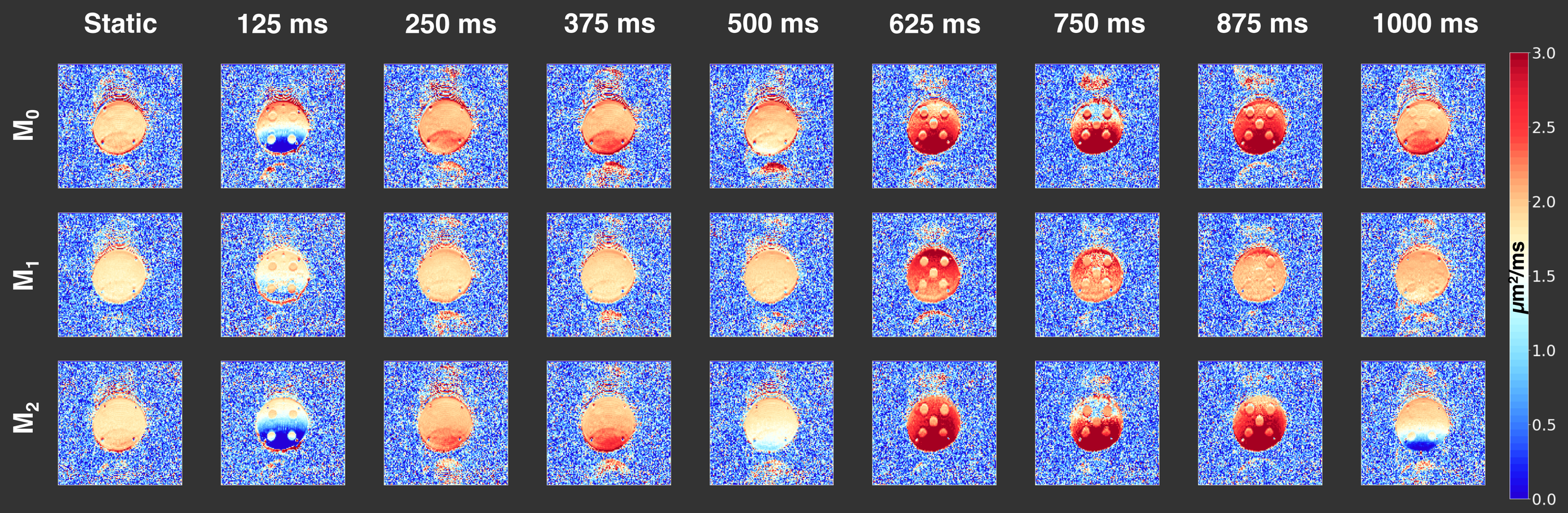
Mean Diffusivity: TE Synchronized



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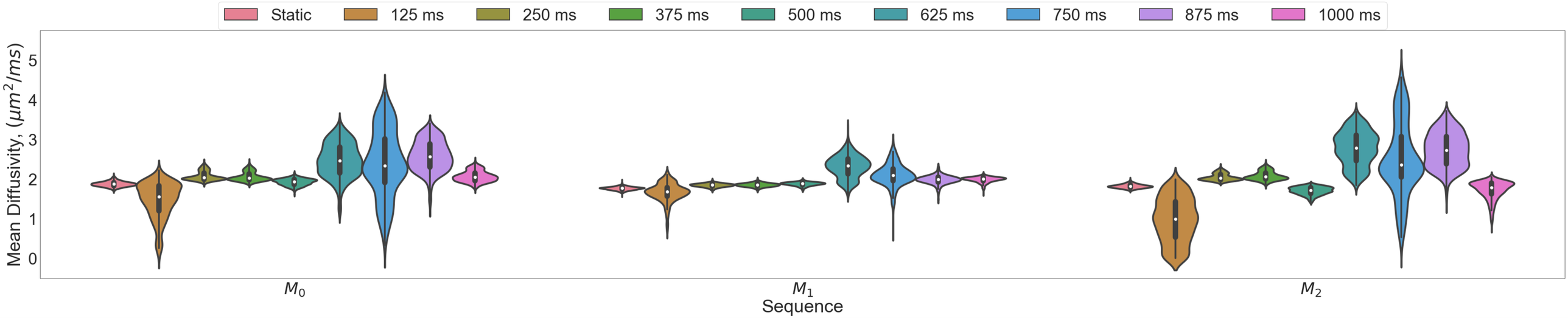

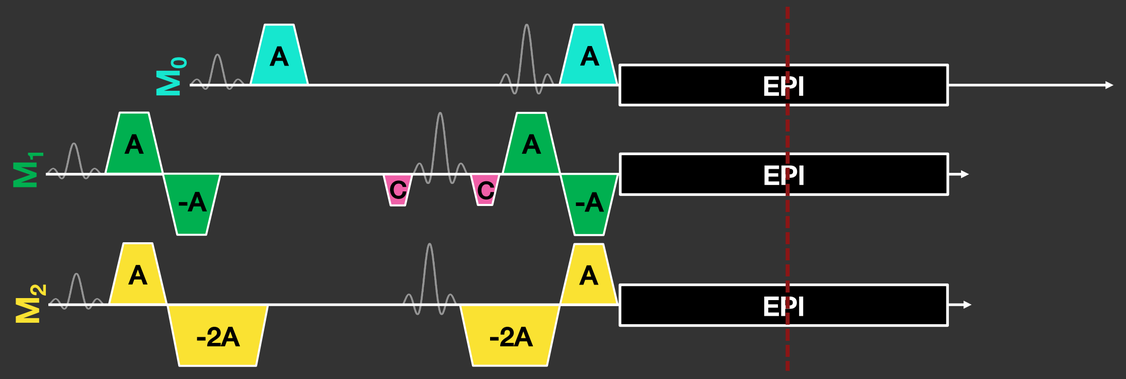

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Future Work:

- Incorporate crushers on M_0 and M_2 sequences to verify our first main finding
- Incorporate an in-plane experiment to further characterize the effects of motion encoding waveforms

THANKS!

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Slides