Low-Field Multi-Parametric MRI: Opportunities and Challenges

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Disclosures

- Research funding provided by:
  - NIH R01CA204189 (PI: Glide-Hurst)
  - Philips Healthcare
- Collaborations with Modus Medical Devices, ViewRay (unrelated to the current work)
- Research in conjunction with Mark Haacke, PhD et al. (WSU) and sequences are not FDA approved

Multiparametric MRI (mpMRI)

- Noninvasive assessment of patho-physiological processes
- Multiple contrasts provide insight compared to a single parameter
- In prostate, PI-RADS V2 recommends obtaining T2-weighted, DWI, DCE, and optional spectroscopy

PI-RADS™ v2

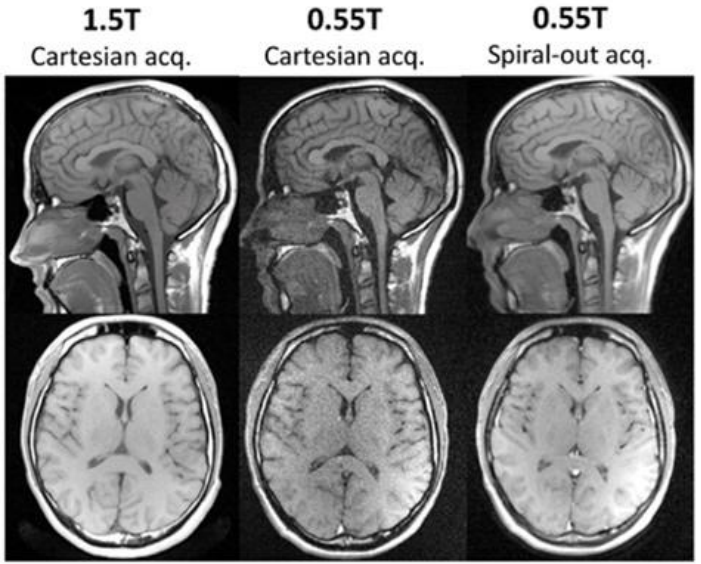
The recommendations in this document focus only on 3T and 1.5T MRI scanners since they have been the ones used for clinical validation of mpMRI. Prostate mpMRI at lower magnetic field strengths (<1.5T) is not recommended unless adequate peer reviewed clinical validation becomes available.

Clinical Motivation: Low Field Strength

- ✓Compact/reduced shielding & footprint
- ✓ Lower costs→wider accessibility
  (only 1/10th of world population has access to MRI[1]?)
- ✓Less local heating/SAR
- ✓ Reduced susceptibility effects
- ✓ Desirable characteristics: short T1 and long T2* for efficient pulse sequence design

[1]http://data.oecd.org/healtheqt/magnetic-resonance-imaging-mri-units.htm

Opportunities in Interventional and Diagnostic Imaging by Using High-performance Low-Field-Strength MRI



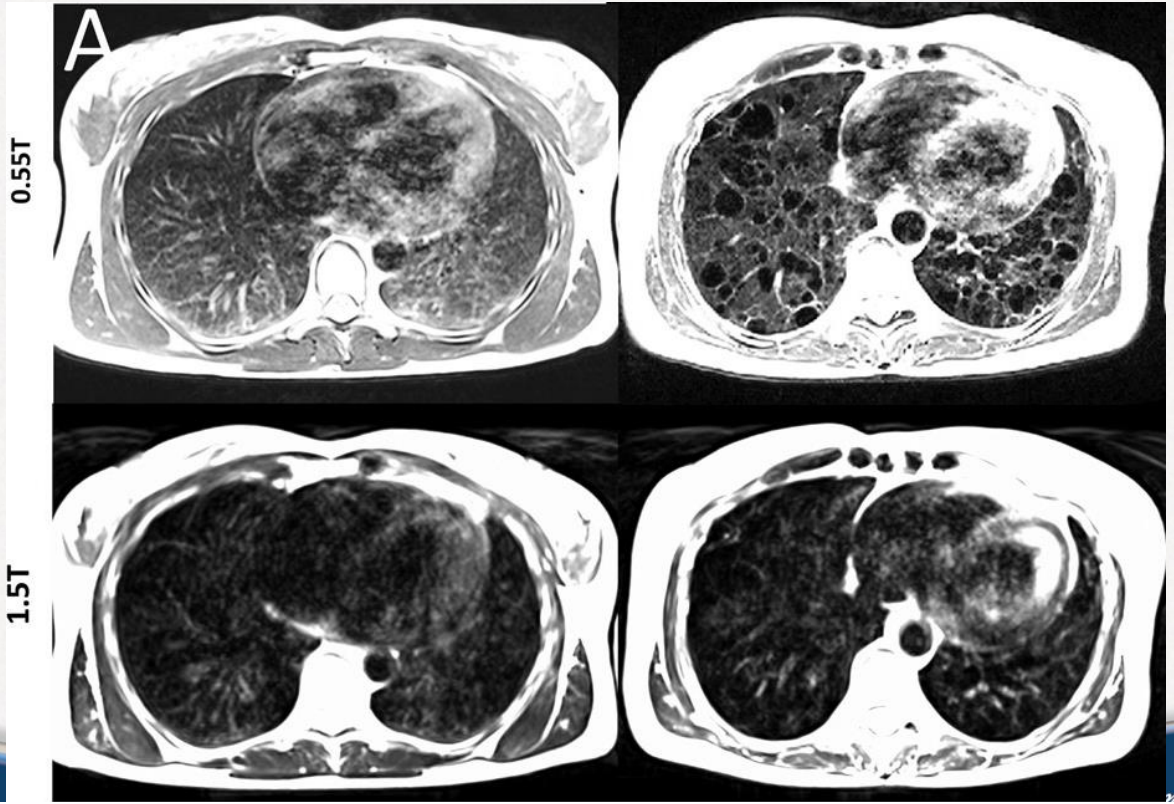
Signal-to-noise ratio–efficient spiral imaging applied for T1-weighted neuroimaging demonstrated in a 23-year-old (axial sections) and a 28-year-old (sagittal sections).

- Eighty-three MRI examinations were performed in 45 study participants by using a custom 0.55-T MRI system that combines low field strength with advanced hardware and imaging methods.
- MRI-guided cardiovascular catheterizations were performed in seven study participants with commercially available metallic guidewires that generated negligible heating during real-time MRI at 0.55 T.

Campbell-Washburn AE et al. Published Online: October 1, 2019
https://doi.org/10.1148/radiol.2019190452

Radiology

Increased intensity/improved homogeneity



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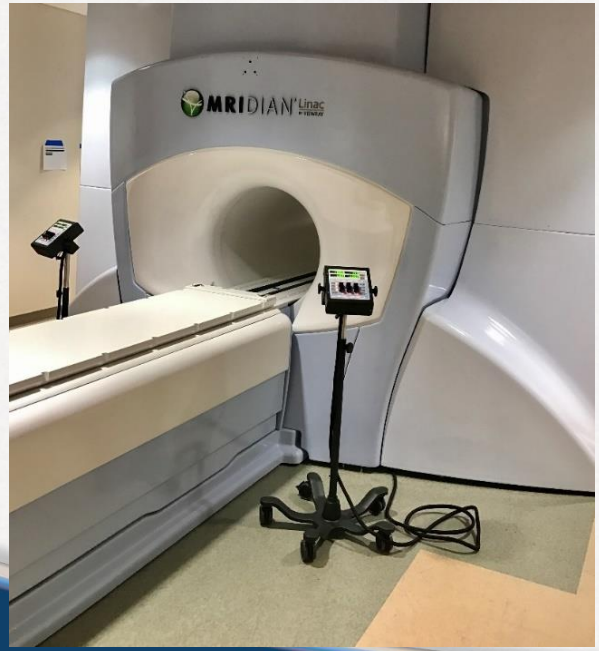
Radiology

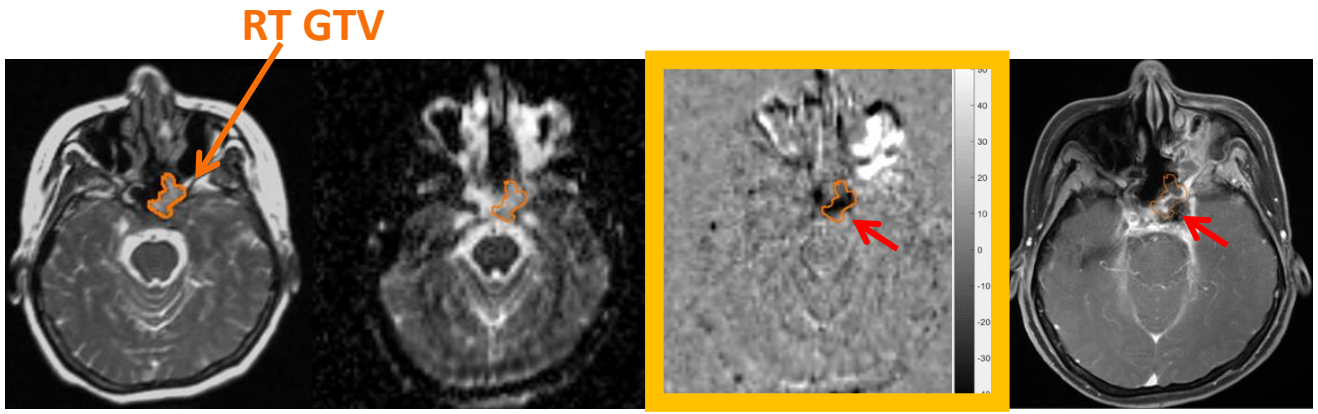
Low-field ViewRay MRIdian MR-Linac



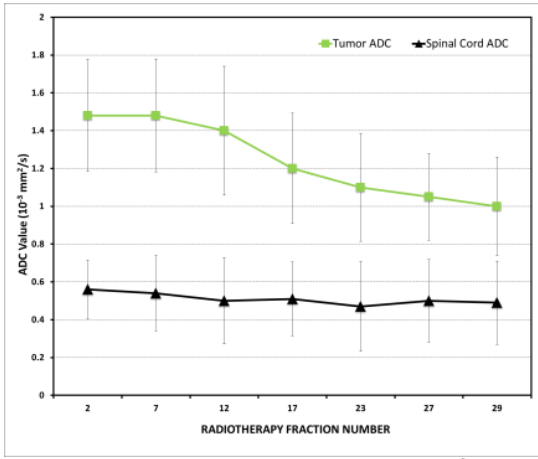
- Split bore 0.35T MR coupled with a 6XFFF linear accelerator
- Dedicated surface coils for patient imaging

MRgRT for Response Prediction

- H&N cancer patient, decreased ADC observed in GTV
- Longitudinal DWI is feasible with the 0.35T ViewRay MRI

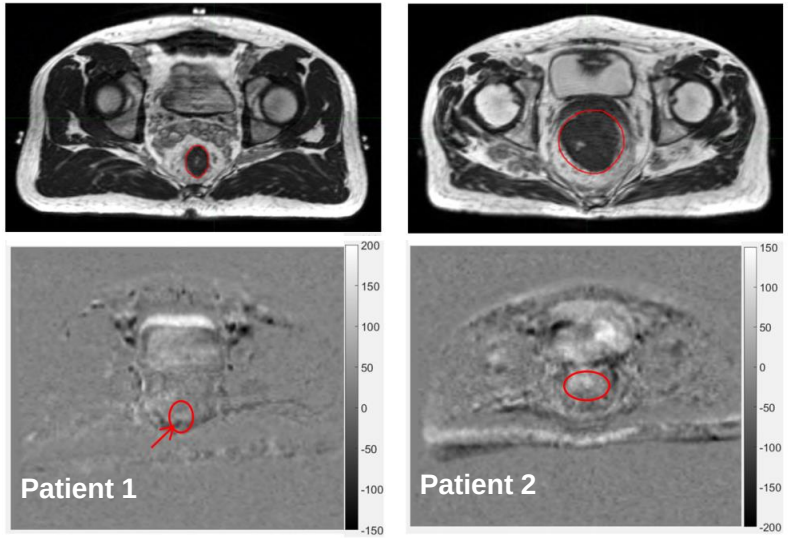


MRI pre-RT | Early ADC map during RT | ADC change slope map throughout RT | MRI 21 months post-RT – confirm recurrence



Slide courtesy of Yingli Yang, PhD

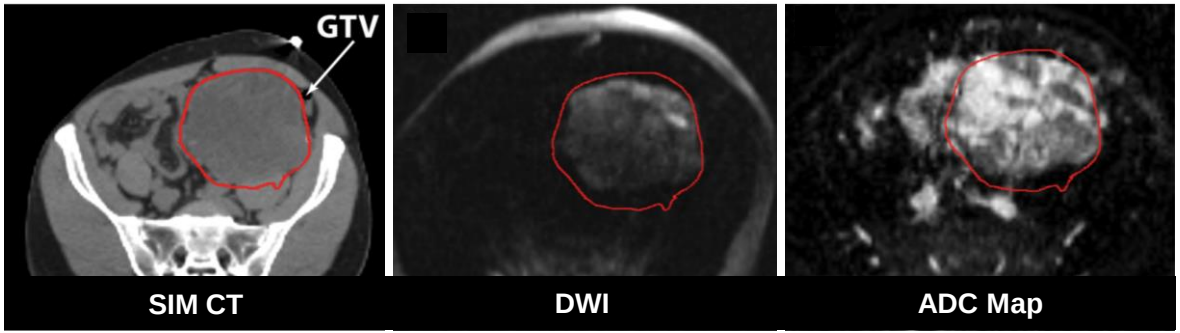
0.35T Co^{60} Response: Rectal Cancer & Sarcoma



Functional diffusion map: Darkened areas suggest treatment-resistant subregions

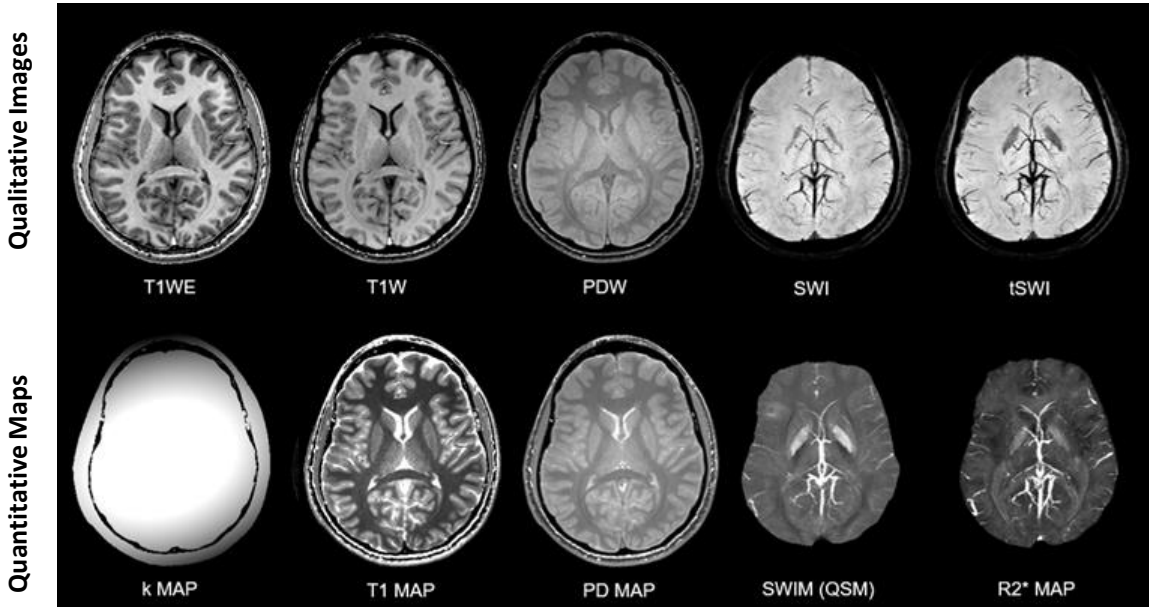
Shaverdian *et al*, BJR, 2017

Yang *et al.*, Med Phys, 2016



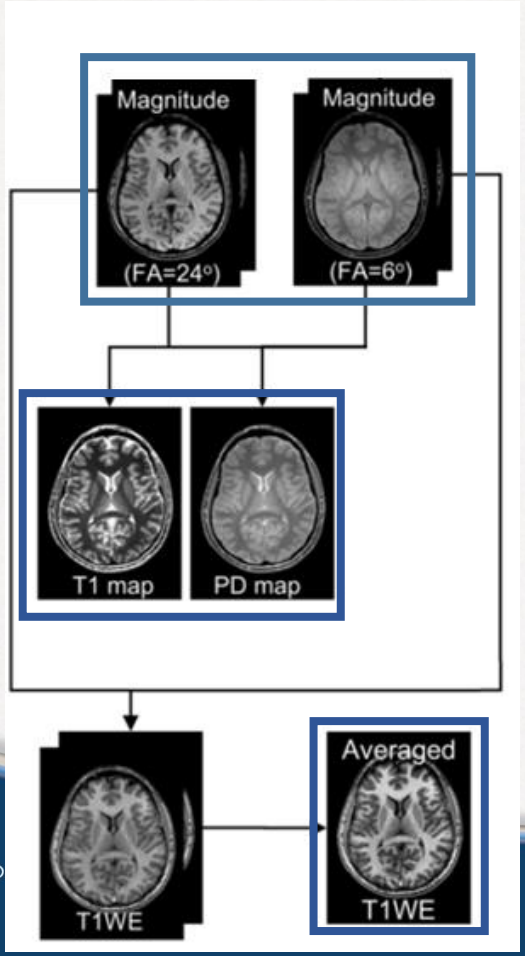
STAGE mpMRI

- STAGE[1-4] employs multi-echo GRE acquisitions with optimal echo times and flip angles
- STAGE obtains multi-contrast qualitative images and quantitative data for studying neuro-degenerative diseases
- Fast (5 mins @ 3T, 10 mins @ 0.35T), 3D high resolution protocol using endogenous tissue contrast

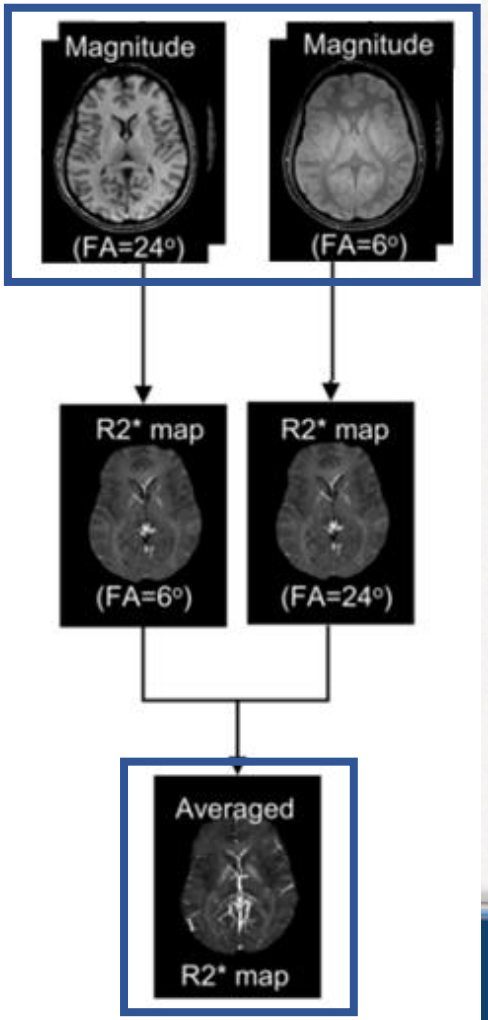


[1] Chen, et al., MRI 2017; [2] Wang, et al., MRI 2017; [3] Chen, et al., MRI 2017; [4] Chen, et al., SPIE 2018

T1 and Proton Density Maps



- T1 Map: quantitative T1 mapping detects enhancing tumor earlier. Serial T1 mapping can be used to generate “differential maps”
- Proton Density Map
- Enhanced T1WE: improved GM/WM contrast-to-noise ratio and image homogeneity than conventional T1W



R2*Maps

- R2*Map can reflect oxygenation state of tumors
- R2*Map differentiates between tumor types: GBMs have high R2* values [5]

[5] Liu et al., Eur Radiol, 2014

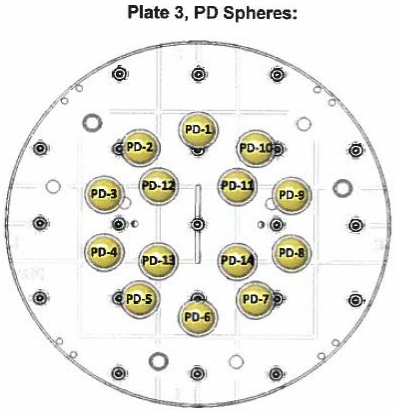
Benchmarking: ISMRM/NIST Phantom

T1 mapping:

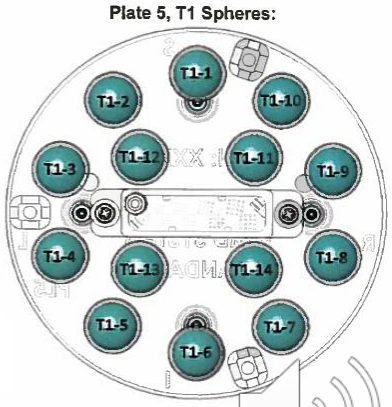
- STAGE- 11 acquisitions
- Compare to standard methods:
  - Variable Flip Angle (VFA) at 0.35T: (2°, 5°, 10°, 20°, 25°, 30°) - 5 acquisitions
  - Inversion Recovery (IR)

Proton Density mapping:

- STAGE – 5 acquisitions, single timepoint



% water
5% - 100%

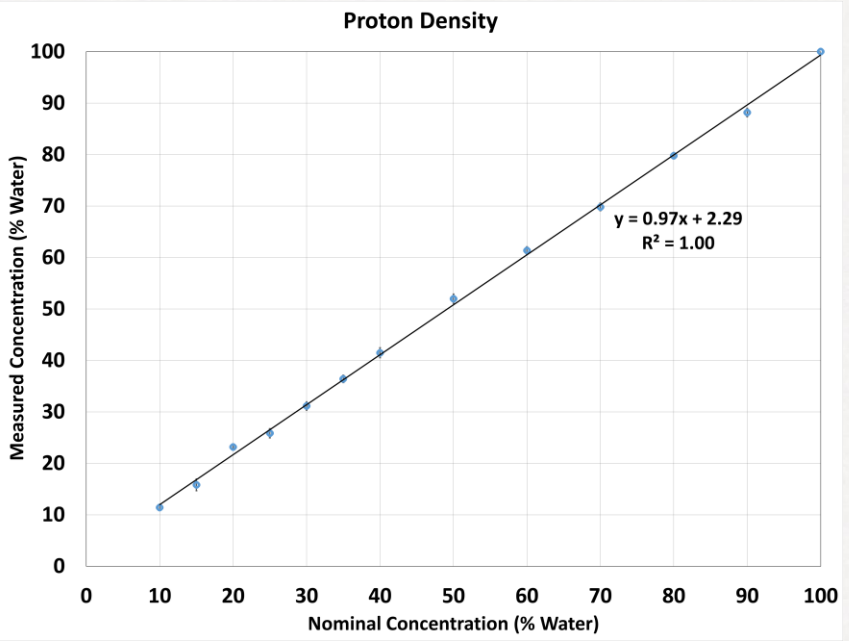


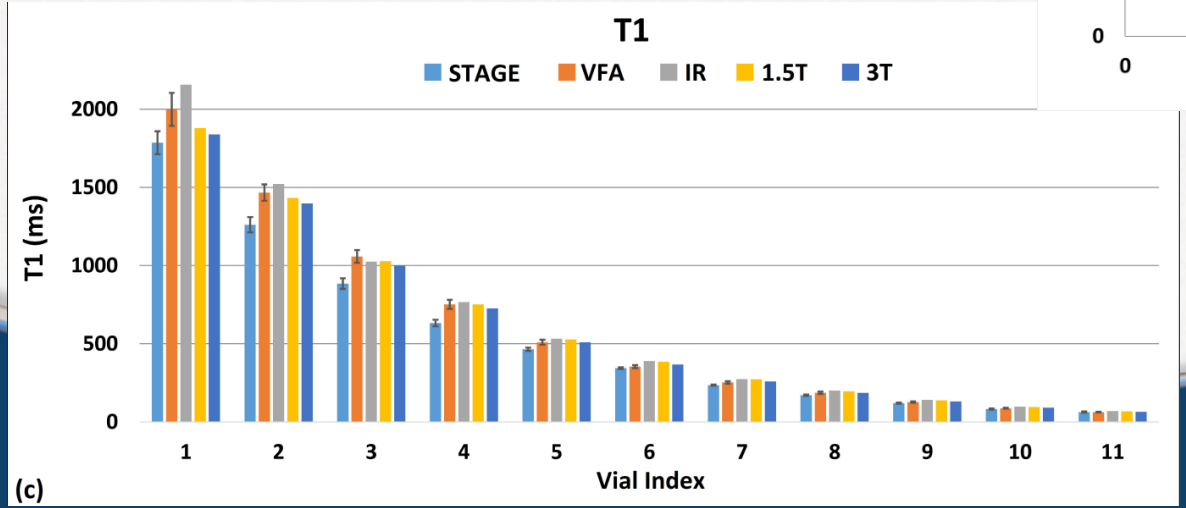
T1 values at
22ms – 2000 ms

Nejad-Davarani, S et al., Medical Physics, 2020

0.35T Benchmarking

- STAGE PD agrees with expected
- Relative error of VFA T1 and STAGE T1 relative to IR were ~7.0- 10.0%
- Relative error for PD was ~8%





Nejad-Davarani, S et al., Medical Physics, 2020

Henry Ford Health System

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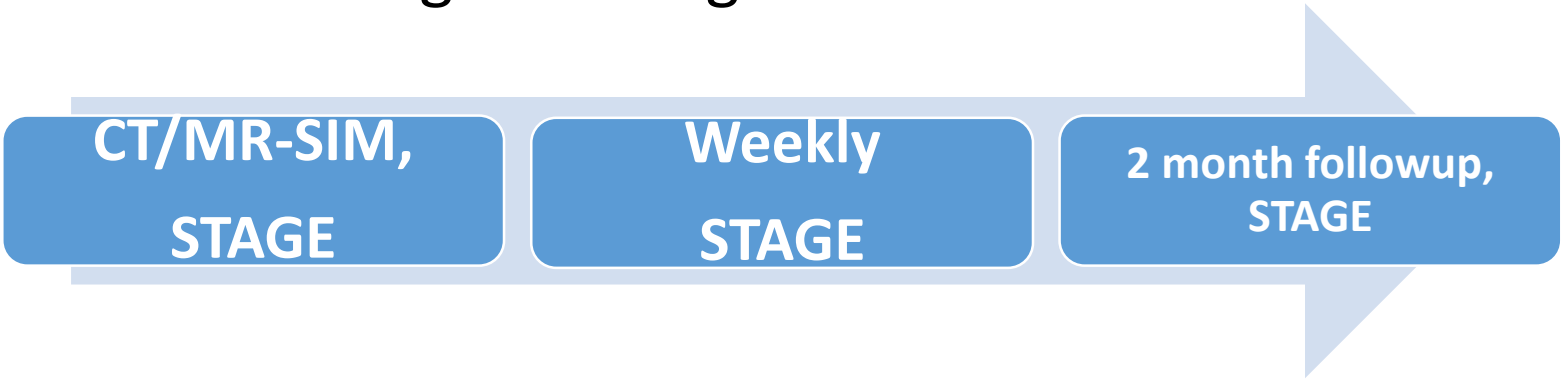
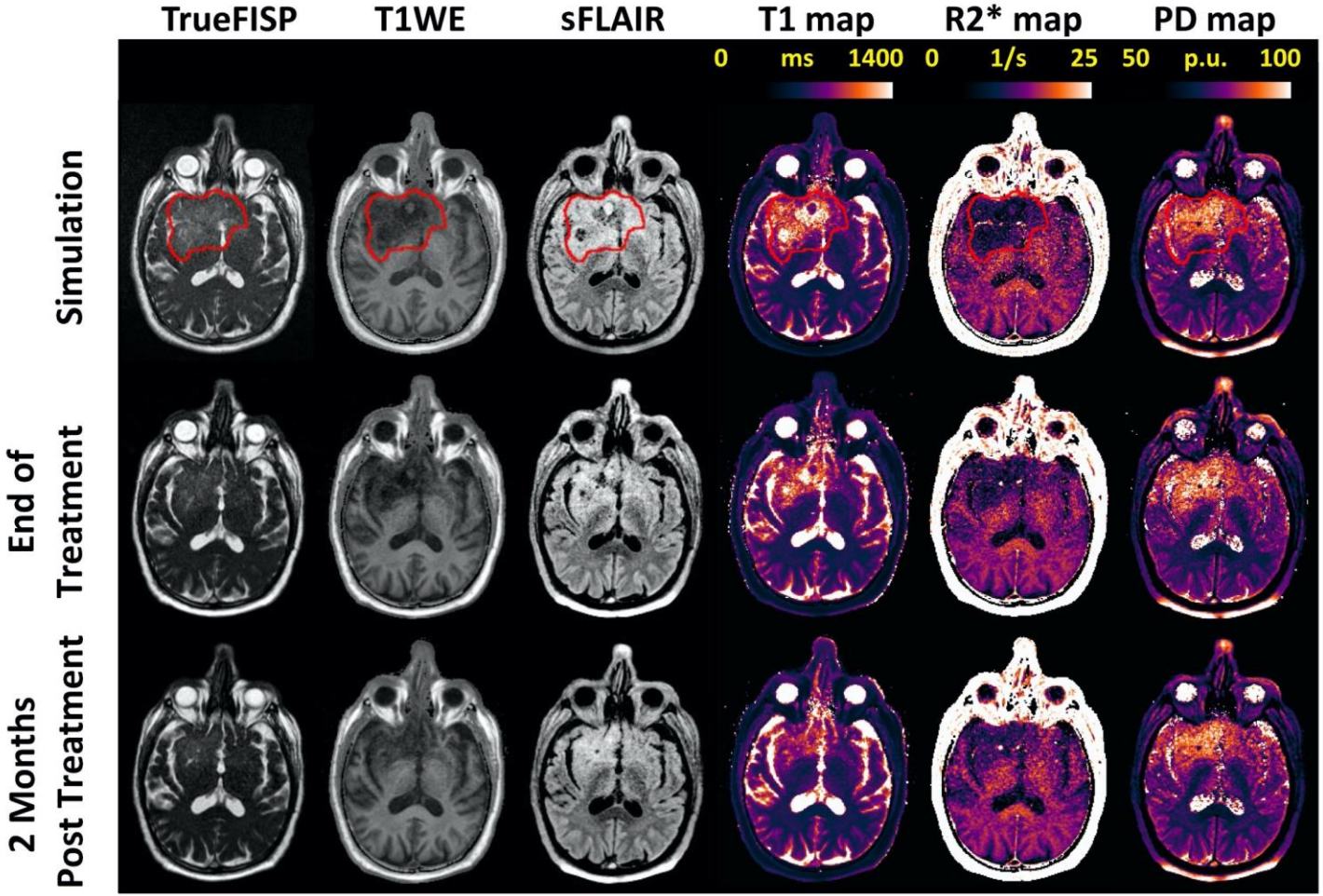
HFCI Prospective Clinical Trial

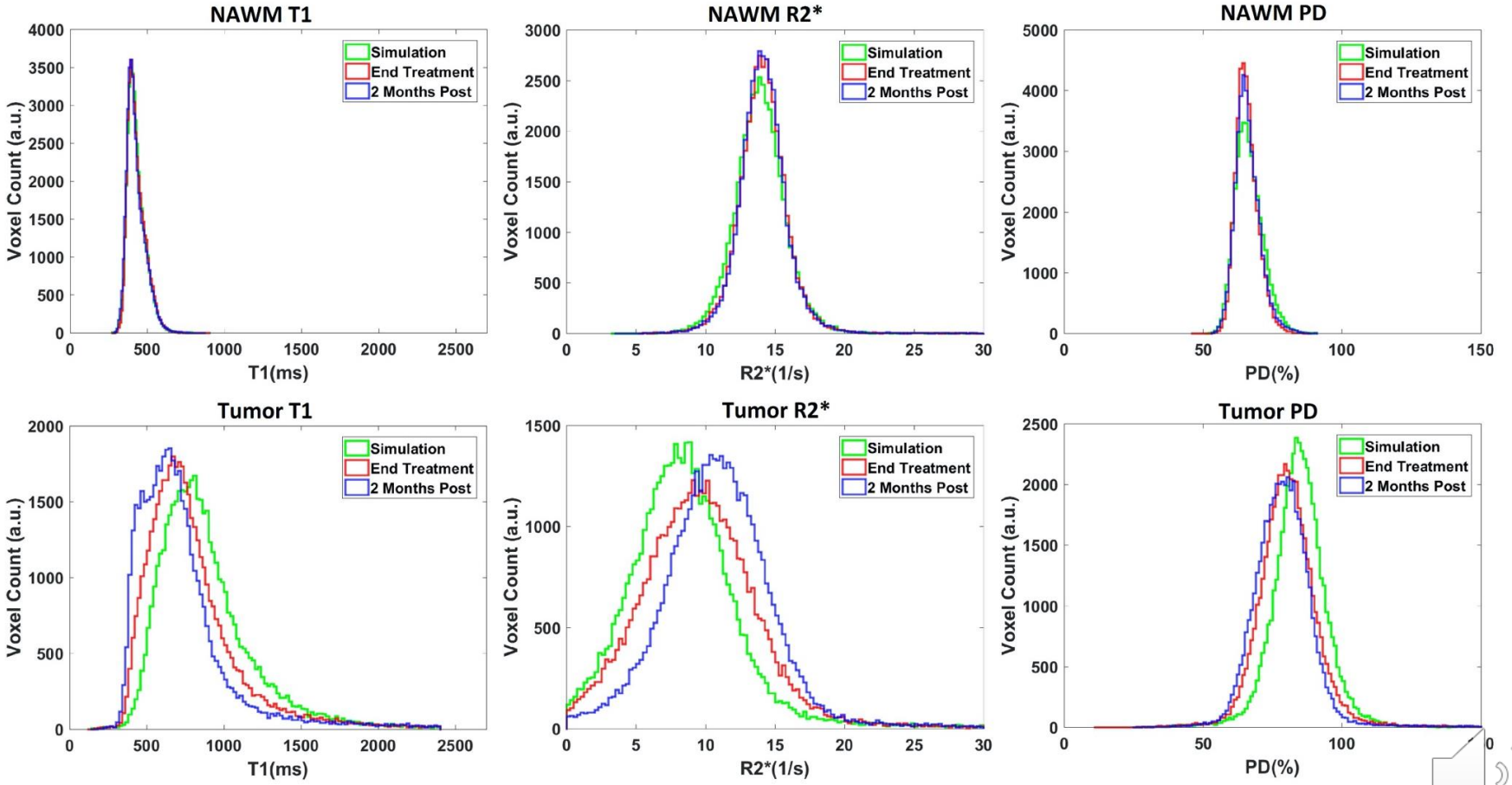
- Feasibility trial of 12 patients imaged and treated on the ViewRay 0.35T MR-linac
- All brain diagnoses eligible



- Spatial correlation with conventional 3T diagnostic MRI and clinical outcomes



Nejad-Davarani, S et al., Medical Physics, 2020



Nejad-Davarani, S et al., Medical Physics, 2020

Potential Applications in Low Field & Future Work

- Low-field mpMRI offers potential to quantify lesion and surrounding normal tissue changes over time
- Phantom benchmarking appears reliable
- Potential to implement in low resource settings or in hybrid MR environments (MR-OR, MR-linac, etc.)
- With a larger cohort, may use quantitative data to correlate to patient outcomes and treatment response assessment

Thank you!