Advanced diffusion modeling characterizes FLAIR white matter hyperintensity types in an aging cohort

Kelly Chang[1], Luke Burke[4], Nina LaPiana[2], Bradley Howlett[2], David Hunt[2], Margaret Dezelar[4], Jalal B. Andre[3], James Ralston[4], Ariel Rokem[1,5], & Christine Mac Donald[2,5]

Departments of [1]Psychology, [2]Neurological Surgery, and [3]Radiology, University of Washington
[4]Kaiser Permanente Washington Health Research Institute, [5]These authors contributed equally
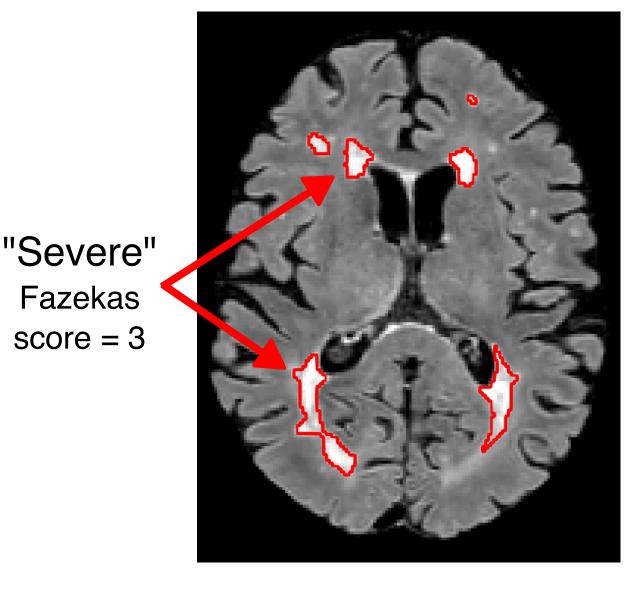
Background

• White matter hyperintensities (WMH) in fluid-attenuated inversion recovery (FLAIR) MRI images are used as an indicator of clinical conditions ranging from multiple sclerosis to cerebrovascular disease[1,2].

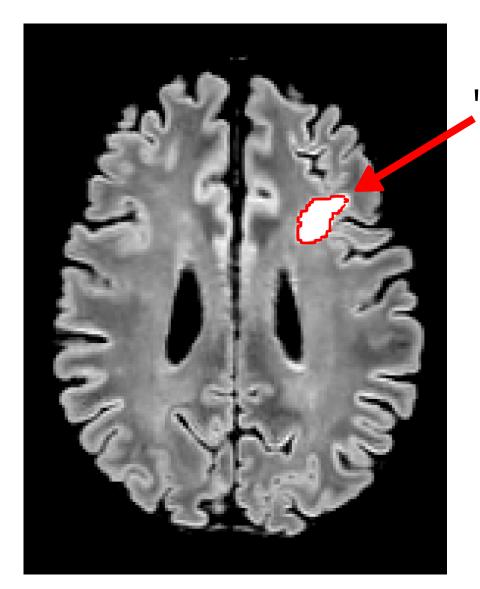• Diffusion MRI (dMRI) and diffusion modeling provides biophysically interpretable tissue properties.

Goal: Use diffusion modeling to characterize the underlying biophysical properties of FLAIR WMH.

Methods

FLAIR processing:

• FLAIR WMH were segmented with a convolutional neural network, HyperMapp3r[3].

• WMH regions of interest were categorized as either periventricular (left) or deep (right) WMH.

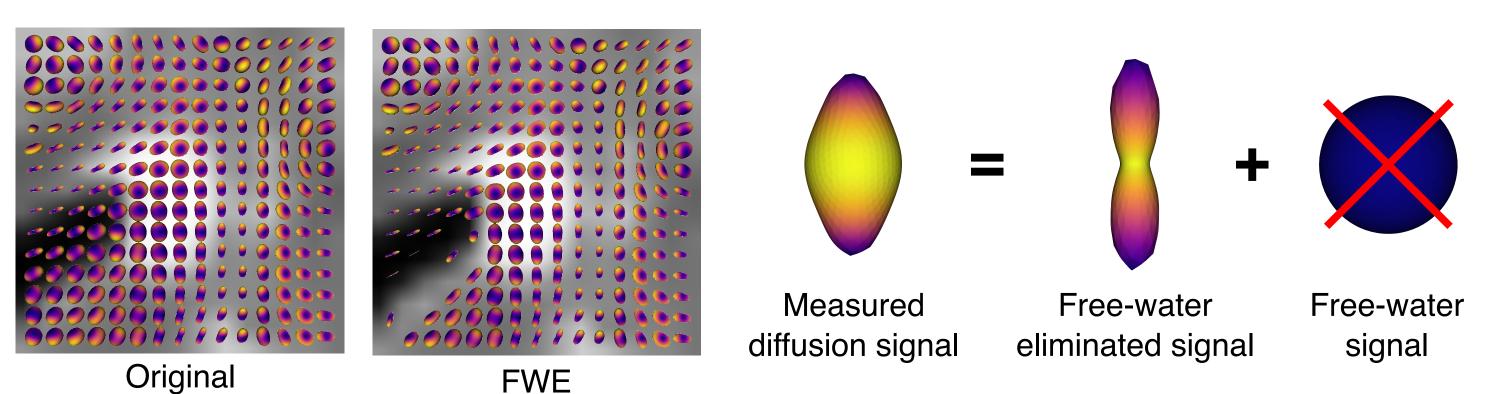"Severe" Fazekas score = 3

"Moderate" Fazekas score = 2

Diffusion models:

• Diffusion kurtosis imaging (DKI) and its White Matter Tract Integrity extension[4].

• Free-water diffusion tensor imaging (FWDTI)[5].

• Mean apparent propagator MRI (MAPMRI)[6].

• Neurite orientation dispersion and density imaging (NODDI)[7].

Tractography methods:

• Tractography was performed with pyAFQ[8] on the original diffusion data and after free-water elimination (FWE)[9].

Measured diffusion signal = Free-water eliminated signal + Free-water signal

Original   FWE

Acknowledgements

ACT ADULT CHANGES IN THOUGHT STUDY
eScience Institute ADVANCING DATA-INTENSIVE DISCOVERY IN ALL FIELDS
NIH National Institute on Aging

References

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[4] Jensen et al. (2005). *Magn Reson Med.*
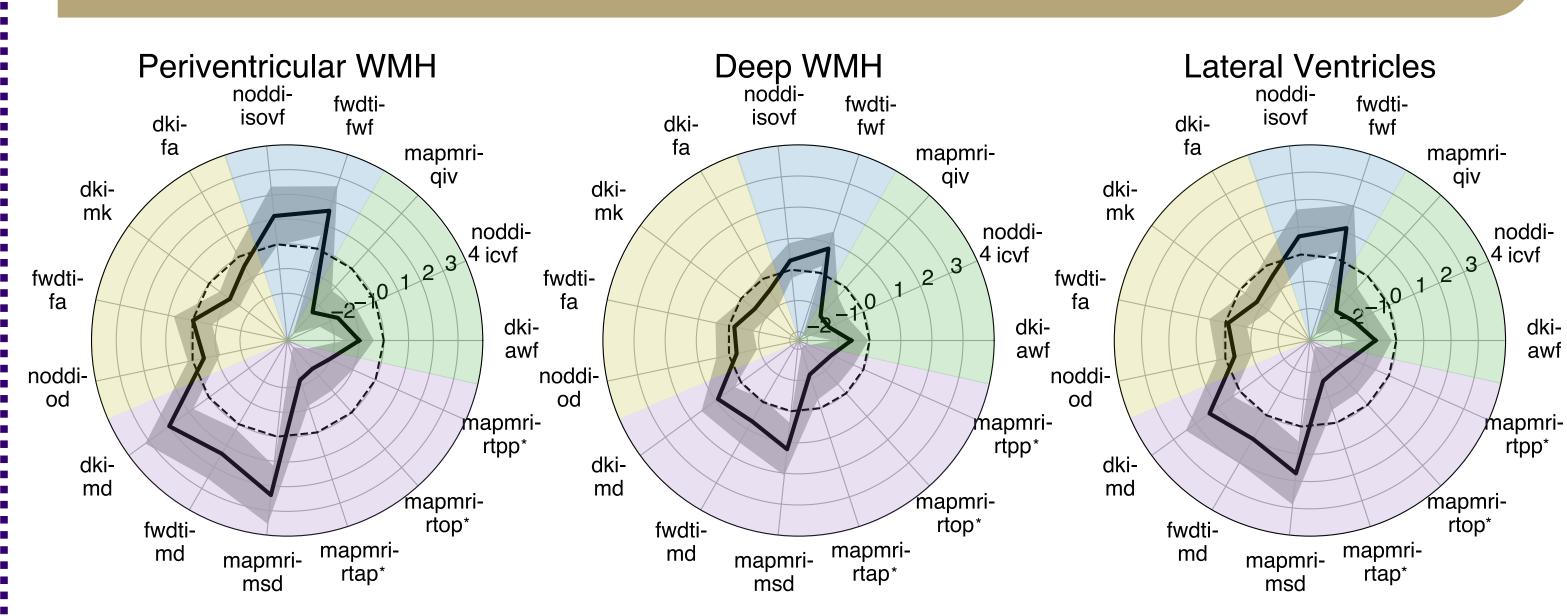[5] Hoy et al. (2014). *NeuroImage.*
[6] Özarslan et al. (2013). *NeuroImage.*
[7] Zhang et al. (2012). *NeuroImage.*
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[9] Henriques et al. (2017). *bioRxiv.*

DIPY   pyAFQ   FWE

Results

Periventricular WMH   Deep WMH   Lateral Ventricles
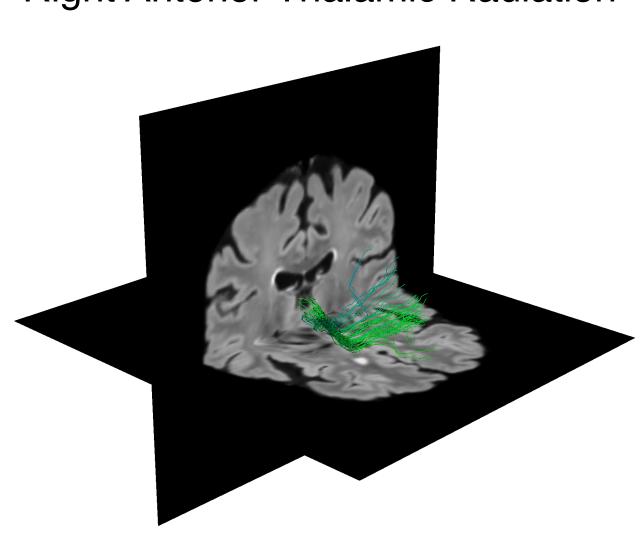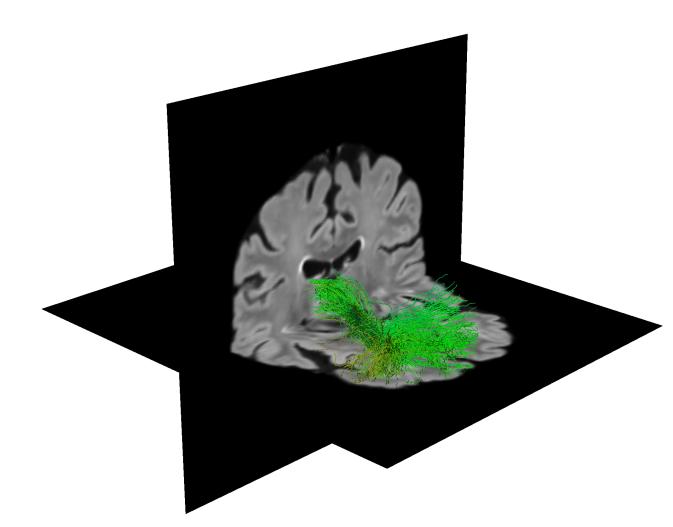
• **FLAIR WMH are characterized by increased mean diffusivity and extracellular water, especially in periventricular WMH.**

• Periventricular WMH's dMRI metric pattern resembles those of the lateral ventricles
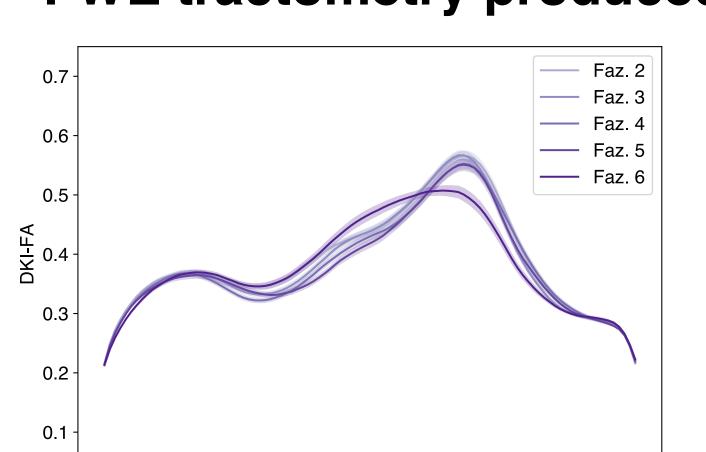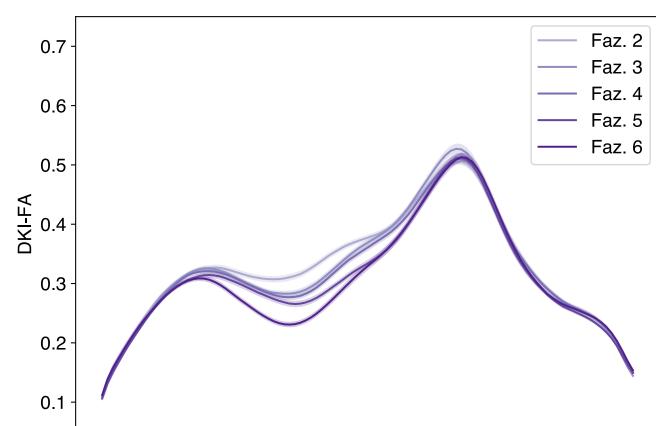
Original Tractography
Right Anterior Thalamic Radiation
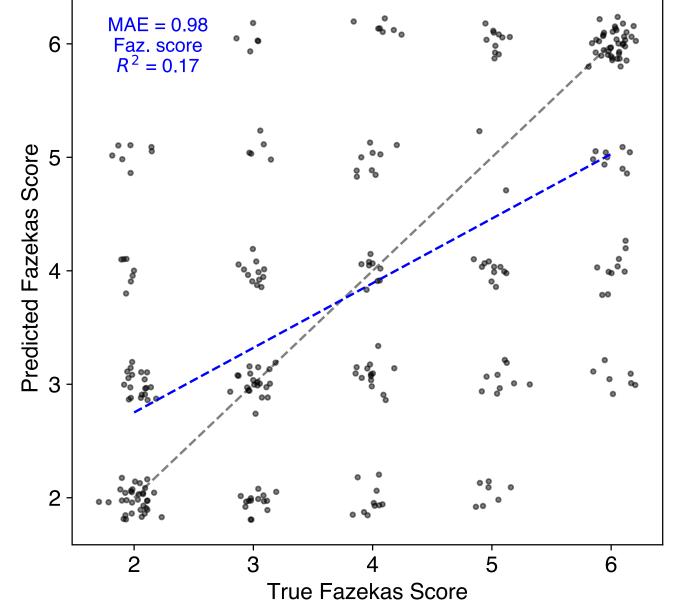
FWE Tractography
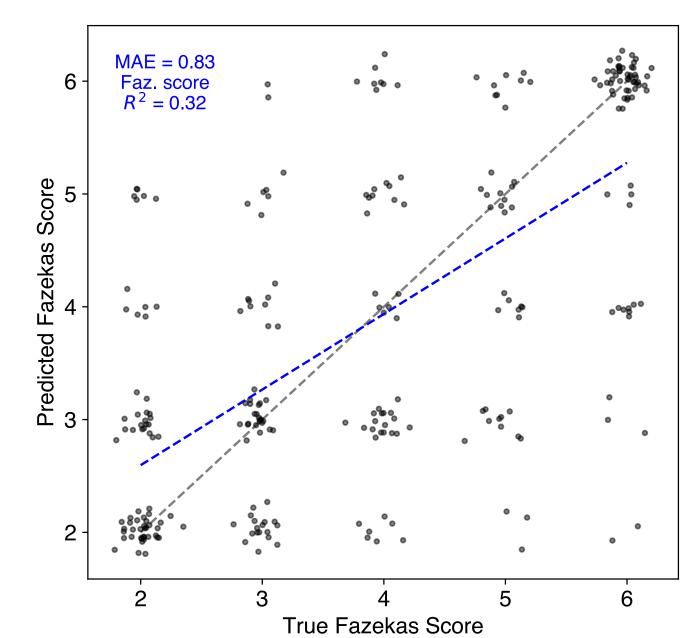Right Anterior Thalamic Radiation

• **FWE tractometry produced fuller tractography results.**

• **FWE tractometry produced tract profiles that better represent Fazekas scores.**

MAE = 0.98 Faz. score R^2 = 0.17

MAE = 0.83 Faz. score R^2 = 0.32

• **FWE tract profiles predict Fazekas scores more accurately than original tract profiles.**

Conclusions

• The patterns observed indicate that periventricular and deep WMH tissue begins to resemble ventricles more than NAWM, particularly in the case of periventricular WMH.

• Free-water elimination in aging brains increases the reliability in all steps of tractometry and improve the accuracy in classification of clinical phenotypes, especially in the presence of WMH.