#1022 Magnetization Transfer Imaging with a Surface Cryogenic Coil

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Background

Importance of Myelin Imaging

- Dys-myelination has been observed in many neuropsychiatric disorders [1]
- Non-invasive measures of myelin content can give key insight into brain health

Magnetization Transfer Imaging (MTI)

- provides estimates sensitive to myelin content [2]
- The Magnetization Transfer (MT) effect can be quantified with the MT ratio (MTR)

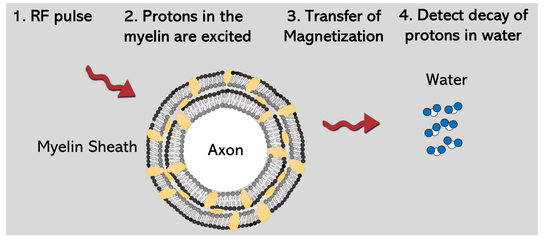

Figure 1. The sensitivity of MTI to myelin. The coil applies a radiofrequency (RF) pulse that excites protons in the myelin. They then transfer their magnetization to protons in water via chemical interactions.

Impact of MRI coil choice

- MTI in rodents has so far only been done with room-temperature coils
- Cryogenically cooled coils (cryocoils) have higher SNR [3]
- Many facilities only have access to *surface* cryocoils

	SNR	B1 homogeneity	Shape
Quadrature (room-temp)	✗	✓	
Surface (cryogenic)	✓	✗	

Figure 2. Comparison of coil types. B1 homogeneity refers to the spatial homogeneity of the RF pulse strength.

Objective

Goal: Implement MTI in mice using a cryogenic surface coil.

Validation: Confirm that this method is sensitive to myelin using the cuprizone-induced mouse model of demyelination.

Benefits: Will increase signal-to-noise ratio (SNR) and allow for same-session acquisition alongside other MRI modalities (e.g. fMRI).

Challenge: Must correct for the ventral signal drop-off due to B1 inhomogeneities caused by the shape of the cryogenic surface coil.

Experimental Design

Validating the sensitivity of the surface cryocoil implementation to myelin:

Age	0 weeks	9 weeks	15 weeks
Data collection			MTI (room-temperature + cryogenic coil)
Treatment	16	0.2% Cuprizone Diet	8
		Control Diet	8

Figure 3. Experimental design. Data was acquired at the Douglas Cerebral Imaging Center using a 7T Bruker Biospec 70/30USR scanner equipped with a Cryoprobe on wild-type (C57BL/6) mice. At 9 weeks of age, 8 mice (n = 4/4 male/female) were started on a powdered diet containing 0.2% (w/w) of the demyelinating chemical cuprizone while a second group of 8 mice received a control diet for 6 weeks. Both groups were then scanned with both the room temperature and cryogenic coils.

Methods

Reducing signal drop-off in surface cryocoil MTR maps:

a) Optimization of the sequence parameters

b) Calibration of MTR values according to the B1 field strength [4]

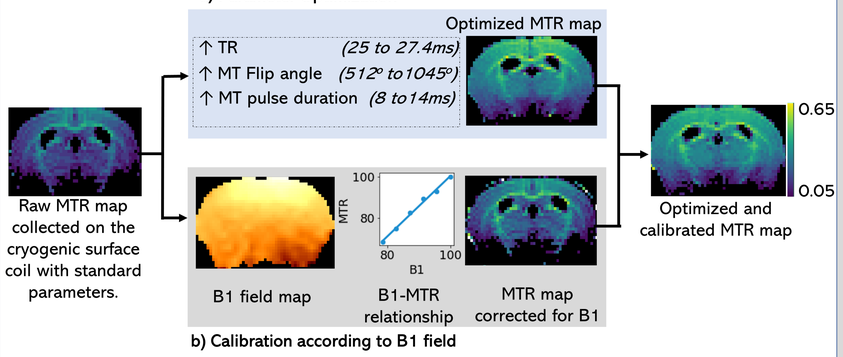

Figure 4. Technique to reduce ventral signal drop-off in MTR maps collected with the surface cryogenic coil. Piloting was done on 4 male control mice. a) Optimized sequence parameters were determined by searching through various combinations of TR, MT flip angle, MT pulse duration and excitation flip angle. The final changes to the parameter values are shown. b) To correct for remaining inhomogeneities in the B1 field, we adjusted the MTR values voxel-wise according to the B1 field map using the linear B1-MTR relationship. The relationship between normalized B1 values and normalized MTR was obtained by progressively decreasing the MT flip angle with each scan to simulate B1 inhomogeneity and calculating the average MTR. [4] The result of performing just this calibration on the raw MTR map is shown.

Results

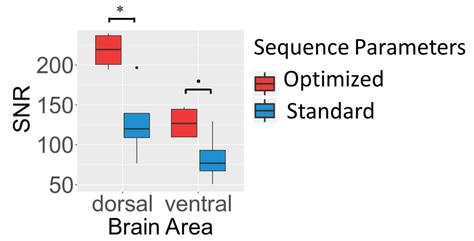

Figure 5. Optimized parameters significantly increased SNR by a factor of 2.8 dorsally ($p < 0.05$) and 3.1 ventrally ($p < 0.08$) compared to standard sequence parameters..

But is the cryocoil better at detecting myelin?

- We compared corrected MTR maps from controls and mice demyelinated with a cuprizone diet
- The surface cryocoil was better at detecting differences between the groups

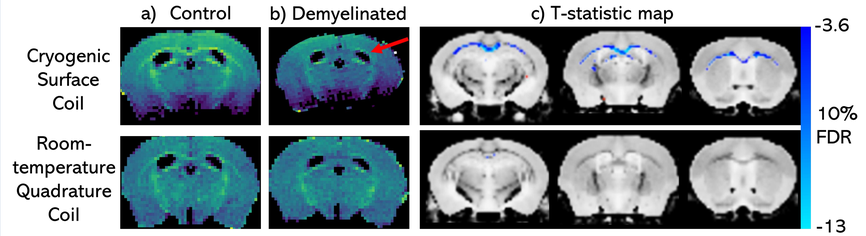

Figure 6. The sensitivity of the surface cryocoil and quadrature room-temperature coil to differences between myelinated mice and demyelinated mice. a) MTR maps from a control mouse, collected with both coil types. b) MTR maps from a mouse that had received the cuprizone diet. The red arrow indicates the missing corpus callosum. c) A map of the t-statistic showing regions where the MTR value is significantly different between groups according to a linear model with sex as a covariate . The cryocoil is sensitive to differences in myelination in the corpus callosum whereas the room-temperature coil is not. A 10% FDR correction is shown for ease of visualization but 5% FDR gives similar results.

Conclusion

- We developed a technique to improve the SNR of MTR mapping in mice
- Surface cryogenic coil maps corrected with this technique are more sensitive to changes in myelin content than the standard quadrature room-temperature coils
- Most past MTR cuprizone studies that used the quadrature room-temperature coil did not report significant cross-sectional results [5, 6, 7]

[1] Nickel, M., & Gu, C. (2018). Regulation of Central Nervous System Myelination in Higher Brain Functions. Neural Plasticity , vol. 2018, Article ID 6436453, 12 pages. **[2]** Heath, F., Hurley, S. A., Johansen-Berg, H. & Sampaio-Baptista, C. (2018). Advances in noninvasive myelin imaging. Developmental Neurobiology 78, 136–151. **[3]** Baltes, C., Radzwillb, N., Bossharda, S., Marekc, D. and Rudin, M. (2009), Micro MRI of the mouse brain using a novel 400 MHz cryogenic quadrature RF probe. NMR in Biomedicine, 22: 834-842. **[4]** Samson, R. S., Wheeler-Kingshott, C. A. M., Symms, M. R., Tozer, D. J. and Tofts, P. S. (2006), A simple correction for B1 field errors in magnetization transfer ratio measurements. Magnetic Resonance Imaging. **[5]** Zaaraoui, W., Deloire, M., Merle M., Girard, C., Raffard, G., Biran, M., Inglese, M., Petry, K.G., Gonen, O., Brochet, B., Franconi, J. & Dousset, V. (2008), Monitoring demyelination and remyelination by magnetization transfer imaging in the mouse brain at 9.4 T. Magnetic Resonance Materials in Physics, Biology and Medicine, 21:357–362. **[6]** Fjær, S., Bø, L., Lundervold, A., Myhr, K.M., Pavlin, T., Torkildsen, Ø., Wergeland, S. (2013). Deep gray matter demyelination detected by magnetization transfer ratio in the cuprizone model. PLoS ONE 8(12):e84162. **[7]** Merkler, D., Boretius, S., Stadelmann, C., Ernsting, T., Michaelis, T., Frahm, J., Bruck, W. (2005). Multicontrast mri of remyelination in the central nervous system. NMR in Biomedicine 18: 395–403.