Multishell diffusion-weighted MRI characterization of chronic active lesions in Multiple Sclerosis

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Introduction

Chronic active Multiple Sclerosis (MS) lesions, seen on susceptibility-weighted MRI as Paramagnetic Rim Lesions (PRL), are associated with increased clinical disability and axonal damage. Diffusion MRI (dMRI) can characterize in vivo PRL's tissue damage, however the tissue microstructure specificity of dMRI models is limited. Here, we characterized PRL's microstructure using 4 different models, including one novel dMRI model: Microstructure Fingerprinting (MF).

Methods

367 lesions (202 PRL and 165 non-PRL) were segmented in 44 MS patients (27 relapsing-remitting, 11 secondary progressive, 6 primary progressive). For each lesion, we calculated volume, quantitative T1 values and diffusion parameters (Table 1) derived from 4 dMRI models: Diffusion Tensor Imaging (DTI), Neurite Orientation Dispersion and Density Imaging (NODDI) and DIstribution of Anisotropic MicrOstructural eNvironments in DWI (DIAMOND) and MF.

Results

PRL were bigger ($p<0.001$) and featured higher T1-values ($p<0.001$) vs non-PRL. DTI and DIAMOND models showed lower fractional anisotropy, higher mean diffusivity and radial diffusivity in PRL vs non-PRL ($p<0.001$). NODDI and MF models showed lower neurite density index and weighted fibre volume fraction ($p<0.001$), suggesting overall impaired axonal integrity/density in PRL vs non-PRL (Table 1, Figure 1).

Conclusion

Consistent with previous data, we show that PRL are characterized by higher axonal damage when compared to non-PRL. Results derived from the MF model are in line with those obtained with DTI, NODDI and DIAMOND, suggesting that this novel dMRI model can be used to study MS lesion pathology. As an advantage, the MF model framework allows further methodological improvement, using more accurate white matter-diffusion simulations.

Disclosures

Authors have no relevant disclosures related to this submission.

	PRL *Mean ± SD*	**non-PRL** *Mean ± SD*	*p*
Volume, mm^3	228,673 ± 290,301	102,998 ± 112,540	< 0,001
T1, ms	1529,872 ± 284,678	1236,189 ± 217,452	< 0,001
DTI_AD, mm^2/s	0,00101 ± 0,00018	0,00096 ± 0,00019	< 0,001
DTI_FA	0,35872 ± 0,11089	0,44450 ± 0,12704	< 0,001
DTI_MD, mm^2/s	0,00074 ± 0,00014	0,00064 ± 0,00013	< 0,001
DTI_RD, mm^2/s	0,00060 ± 0,00015	0,00047 ± 0,00014	< 0,001
NODDI_fExtra	0,58044 ± 0,10657	0,48462 ± 0,10705	< 0,001
NODDI_NDI	0,27335 ± 0,08745	0,33077 ± 0,10099	< 0,001
NODDI_fIso	0,14599 + 0,10826	0,18461 ± 0,09603	< 0,001
NODDI_odi	0,25121 ± 0,08352	0,23366 ± 0,07619	0,097
DIAMOND_wAD, mm^2/s	0,00182 ± 0,00029	0,00175 ± 0,00028	0,018
DIAMOND_wFA	0,54310 ± 0,12855	0,63083 ± 0,13551	< 0,001
DIAMOND_wMD, mm^2/s	0,00107 ±0,00016	0,00095 ± 0,00017	< 0,001
DIAMOND_wRD, mm^2/s	0,00070 ± 0,00018	0,00054 ±0,00020	< 0,001
MF_frac_CSF	0,26621 ± 0,15471	0,20683 ± 0,14503	< 0,001
MF_frac_ftot	0,73357 ± 0,15500	0,79317 ± 0,14503	< 0,001
MF_fvf_tot	0,14803 ± 0,06889	0,20792 ± 0,08798	< 0,001
MF_wfvf	0,19508 ± 0,06413	0,25581 ± 0,08374	< 0,001

Table 1 - Mean volume, T1 times and diffusion parameters of DTI, NODDI, DIAMOND and MF models for PRL and non-PRL lesions.
Abbreviations: **DTI_AD:** DTI Axial Diffusivity **DTI_FA:** DTI Fractional Anisotropy **DTI_MD:** DTI Mean Diffusivity **DTI_RD:** DTI Radial Diffusivity **NODDI_fExtra:** NODDI Extracellular Volume Fraction **NODDI_NDI:** NODDI Neurite Density Index **NODDI_fIso:** NODDI Free Water Volume Fraction **NODDI_odi:** NODDI Orientation Dispersion Index **DIAMOND_wAD:** DIAMOND Axial Diffusivity **DIAMOND_wFA:** DIAMOND Fractional Anisotropy **DIAMOND_wMD:** DIAMOND Mean Diffusivity **DIAMOND_wRD:** DIAMOND Radial Diffusivity **MF_frac_CSF:** MF fraction CSF **MF_frac_ftot:** MF Total Tissue Fraction **MF_fvf_tot:** MF Total Fibre Volume Fraction **MF_wfvf:** MF Weighted Fibre Volume Fraction

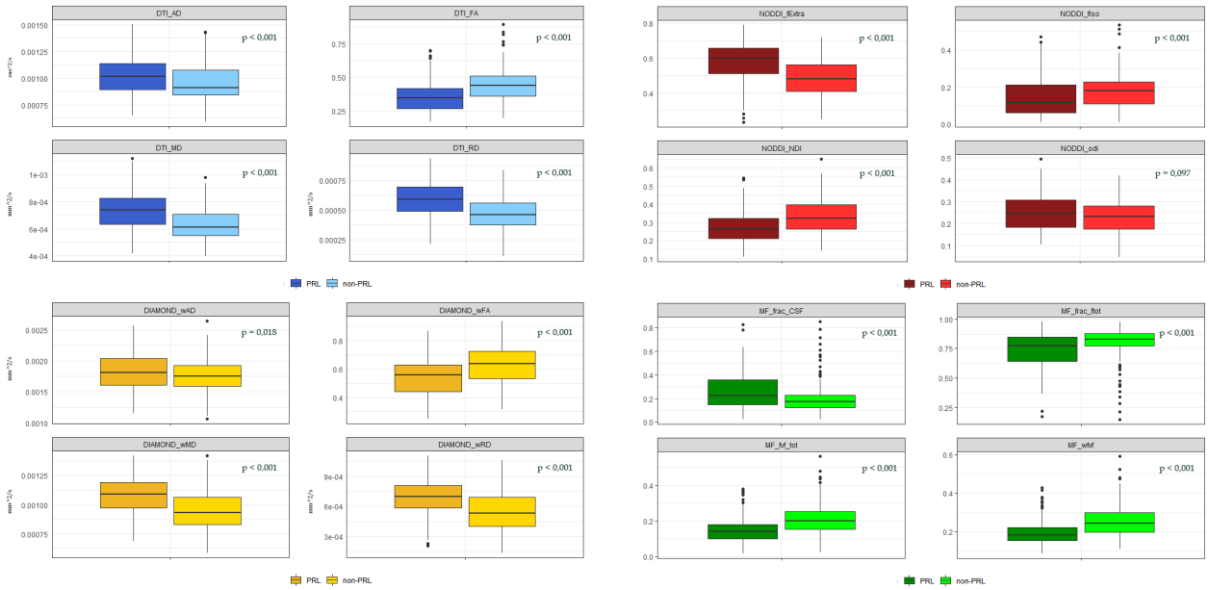

Figure 1 – Boxplot of average DTI (blue), NODDI (red), DIAMOND (yellow) and MF (green) dMRI model parameters in PRL and non-PRL lesions.

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