7 TESLA PHASE RIM AND CORTICAL LESIONS IN MULTIPLE SCLEROSIS AS MARKERS OF DISEASE PROGRESSION

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INTRODUCTION:

In multiple sclerosis, individual lesion-type patterns on MRI might be valuable for predicting clinical outcome and monitoring treatment effects. Neuropathological and imaging studies consistently show that cortical lesions contribute to disease progression.

7-Tesla MRI has allowed the identification of novel radiological markers of MS pathology as chronic active white matter lesions harboring a paramagnetic rim on susceptibility-weighted magnetic resonance imaging [1]. This so called 'rim lesions' has been associated with an aggressive form of multiple sclerosis [2].

It is, however, still uncertain how these two types of lesions relate to each other, or which one plays a greater role in disability progression.

OBJECTIVES:

In this longitudinal study, in a heterogeneous MS cohort, we aimed to characterize the prevalence, distribution and evolution of cortical and chronic rim lesions detected on susceptibility-weighted 7-Tesla images.

The main objective was to assess the cumulative power as well as individual importance of cortical and chronic rim lesions, alongside with traditional imaging markers, in predicting disease stage and disability progression using a modern machine learning algorithm based on extreme gradient boosting (XGBoost) techniques.

We specifically selected this machine learning classifier algorithm as it has been shown that it performs extremely well with a population size of between 50 and 100.

METHODS:

Study participants: 100 MS patients [relapsing remitting (RRMS) N=74, secondary progressive (SPMS) N=26].
EDSS score obtained over 3.2 years ±2.3 in 71 MS patients

MRI Protocol and Image Analysis:

7-Tesla 2D T2*-weighted images (magnitude and phase images for lesion segmentation).

3-Tesla 3D T1-weighted scans (Freesurfer reconstruction, cortical and subcortical segmentation, coregistration with 7-T images)

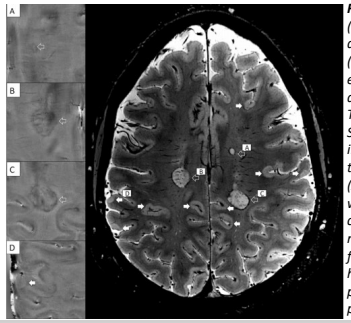


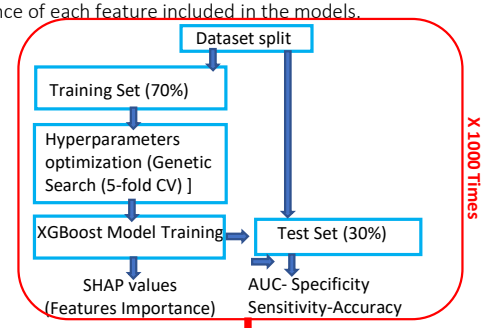
***Figure 1**: Cortical (white arrows) and rim lesions (open arrows) examples detected with 7-T T2*-w images. Some lesions, involving either the white matter (A-C) or both white and cortical grey matter (D) are featuring a hypointense peripheral rim on phase images*

Classification analysis and feature importance:

We used the XGBoost method to:

- generate prediction models for MS disease staging & EDSS progression
- to illustrate the importance of each feature included in the models.

Predictor variables
Rim presence or absence
Rim category (<3 or ≥4 rim lesions)
Rim lesion count
Rim lesion volume
Rimless white matter lesion count
Rimless white matter lesion volume
Intracortical lesion count
Intracortical lesion volume
Leukocortical lesion count
Leukocortical lesion volume
Normalized white matter volume
Normalized thalamic volume
Normalized subarachnoid CSF
Normalized intraventricular CSF
Cortical thickness
Age
Age at MS onset
Sex



OUTPUT

- Performance: Mean±SD AUC- Specificity-Sensitivity-Accuracy values
- Features Importance: SHAP values

RESULTS:

Prediction of MS disease staging

Model Performance:
AUC: 0.82±0.008, sensitivity: 0.78±0.09,
accuracy: 0.77±0.07, specificity: 0.73±0.17

Top 6 contributors to the prediction :
Normalized White Matter Volume;
Normalized Thalamic Volume;
Rimless White Matter lesions count and volume;
Leukocortical lesion volume; Normalized Intraventicular CSD volume

Prediction of EDSS progression

Model Performance:
AUC: 0.69±0.11, sensitivity: 0.71±0.10,
accuracy: 0.68±0.09, specificity: 0.58±0.21

Top 6 contributors to the prediction :
Normalized Subarachnoid CSF; Rim Lesions Volume and Count; Leukocortical lesion volume; Normalized White Matter Volume;
Normalized Intraventicular CSF.

Influential predictors of MS disease staging

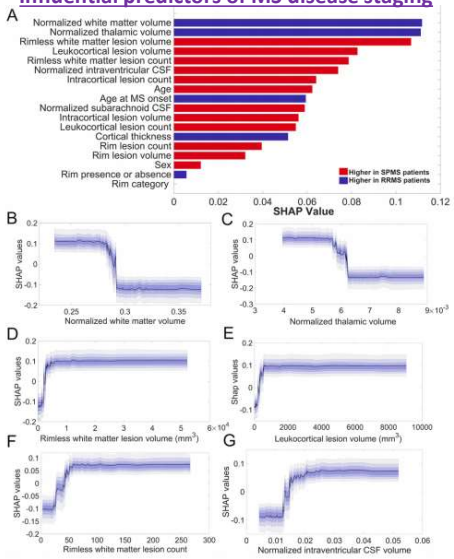


Figure 2:
Influential predictors of MS disease staging.
(A): The resulting SHAP features ranking derived from XGBoost model lists, in descending order, starting with the most significant features in the prediction of EDSS progression in multiple sclerosis. (B-G): The partial SHAP dependence plots (median and confidence intervals across repetitions, B-G) for the top six contributors to the prediction.

Influential predictors of EDSS progression

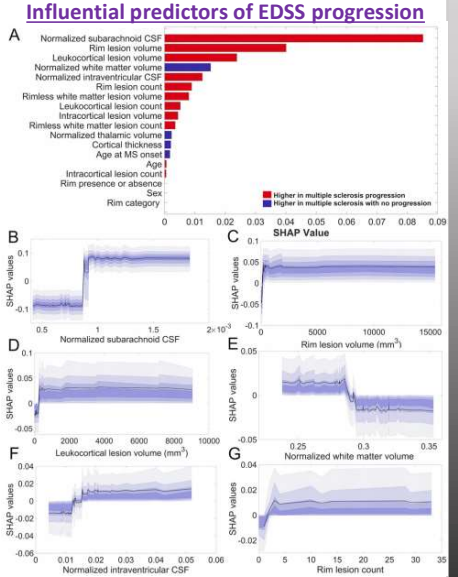


Figure 3 :
Influential predictors of EDSS progression in multiple sclerosis.
(A): The resulting SHAP features ranking derived from XGBoost model lists, in descending order, starting with the most significant features in the prediction of EDSS progression in multiple sclerosis. (B-G): The partial SHAP dependence plots (median and confidence intervals across repetitions, B-G) for the top six contributors to the prediction.

TAKE HOME MESSAGES:

- Cortical and rim lesion types were main predictors of EDSS progression (Figure 3).
- Importance of cortical and rim lesion was lower in discriminating between RRMS/SPMS patients (Figure 2). The highest ranked predictors of the disease stage identified were the traditional MRI metrics of white matter and thalamic atrophy and the rimless white matter lesion volume.
- the combined evaluation of rim and cortical lesions volumes in MS might result in an improved ability to distinguish the patients susceptible to experience a progression of the neurological disability and could influence the therapeutic decision [3]

REFERENCES:

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