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A Clustering Analysis of MS Lesions with T1-&T2-weighted, Diffusion, QSM, and MTR Imaging

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INTRODUCTION

- Multiple Sclerosis (MS) is an autoimmune degenerative disorder affecting the central nervous system, often characterized by the presence of lesions in the white matter apparent on T2- and T1-weighted MR images
- MS lesions are also characterized by
  - reductions:
    - fractional anisotropy (FA) (Roosendaal et al., 2009)
    - magnetic transfer ratio (MTR),
  - increases in:
    - mean diffusivity (MD)
    - magnetic susceptibility (QSM) (Chen et al., 2014),
- Changes in quantitative MRI parameters listed above are caused by demyelination, cell-loss, and hemosiderin deposits (Haacke & Makki, et al., 2009)
- The possibility of characterizing these lesions according to their features across many contrasts requires further exploration
- We aim to extend current knowledge through quantitative MR measures as well as lesion volume on T1-and-T2 images
- We use a dimension-reduction technique, known as t-Distributed Stochastic Neighbor Embedding (t-SNE), followed by a clustering algorithm to assign lesions to fixed numbers of independent classes, which can then be analyzed for feature differences

METHODS

- 207 relapsing remitting MS (RRMS) patients (155-F, mean age 44, ranging from 23 to 60) undergoing an approved disease modifying therapy were scanned on a 3T MR scanner (GE Discovery 750)
- T1w, FLAIR, QSM, DTI, and MTR images were acquired 3D T1w and FLAIR images were acquired with isotropic 1 mm resolution
- An 8-echo monopolar GRE was collected and used to calculate QSM (Sun et al., 2018)
- DTI data was acquired with a 45-direction b=1000 protocol
- MT contrast was generated using an RF pulse 1600 Hz off-resonance
- All images were registered to the T1w for each subject using ANTs (Advanced Normalization Tools v2.1. 2018)
- WM lesions were segmented using FreeSurfer (FreeSurfer v6.0.0. 2018) and a lesion predication algorithm in the LST toolbox of SPM (Schmidt et al., 2012) for T1 and FLAIR images, respectively.
- MD, FA, susceptibility (QSM), MTR, and volumes were calculated for every lesion
- This parameter space was reduced to two dimensions using the TSNE algorithm, which uses a non-linear projection to define relationships between high-dimensional points in a low-dimensional space
- This was followed by a density-based spatial clustering of applications with noise (DBSCAN) algorithm to separate the TSNE processed data into differentiable clusters.

RESULTS

- Figure 1 Shows examples of the lesion metrics
- Figure 2 Shows examples of clustering in in the TSNE space

CONCLUSIONS

- Our analysis suggests the existence of distinct MS lesion categories based on a collective evaluation of diffusion metrics, QSM, MTR, and volume
- The use of TSNE to preprocess the parameter space reduced the dimensionality of lesion variables into a 2D space, improving the application of the DBSCAN clustering algorithm and demonstrating the presence of 4 unique clusters, or lesion 'types'
- We aim to test alternate metrics to determine if these lesion classes are replicated

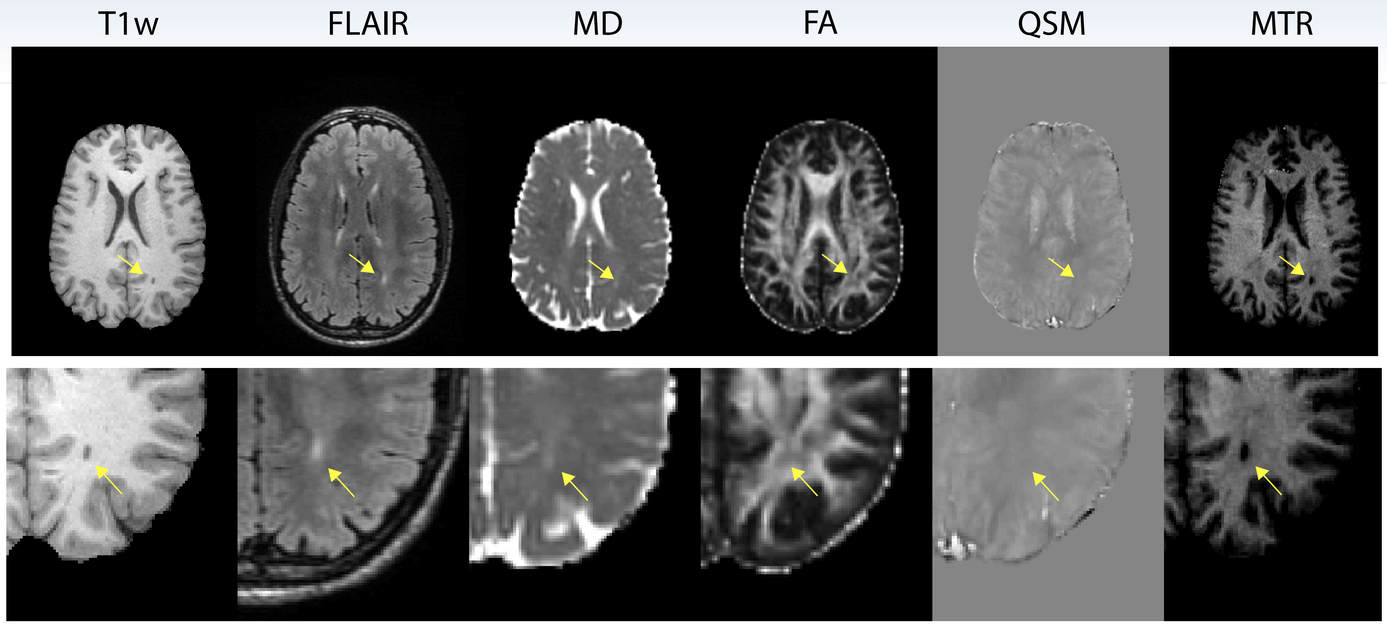

Figure 1: Examples of MS lesions in each of the contrast types

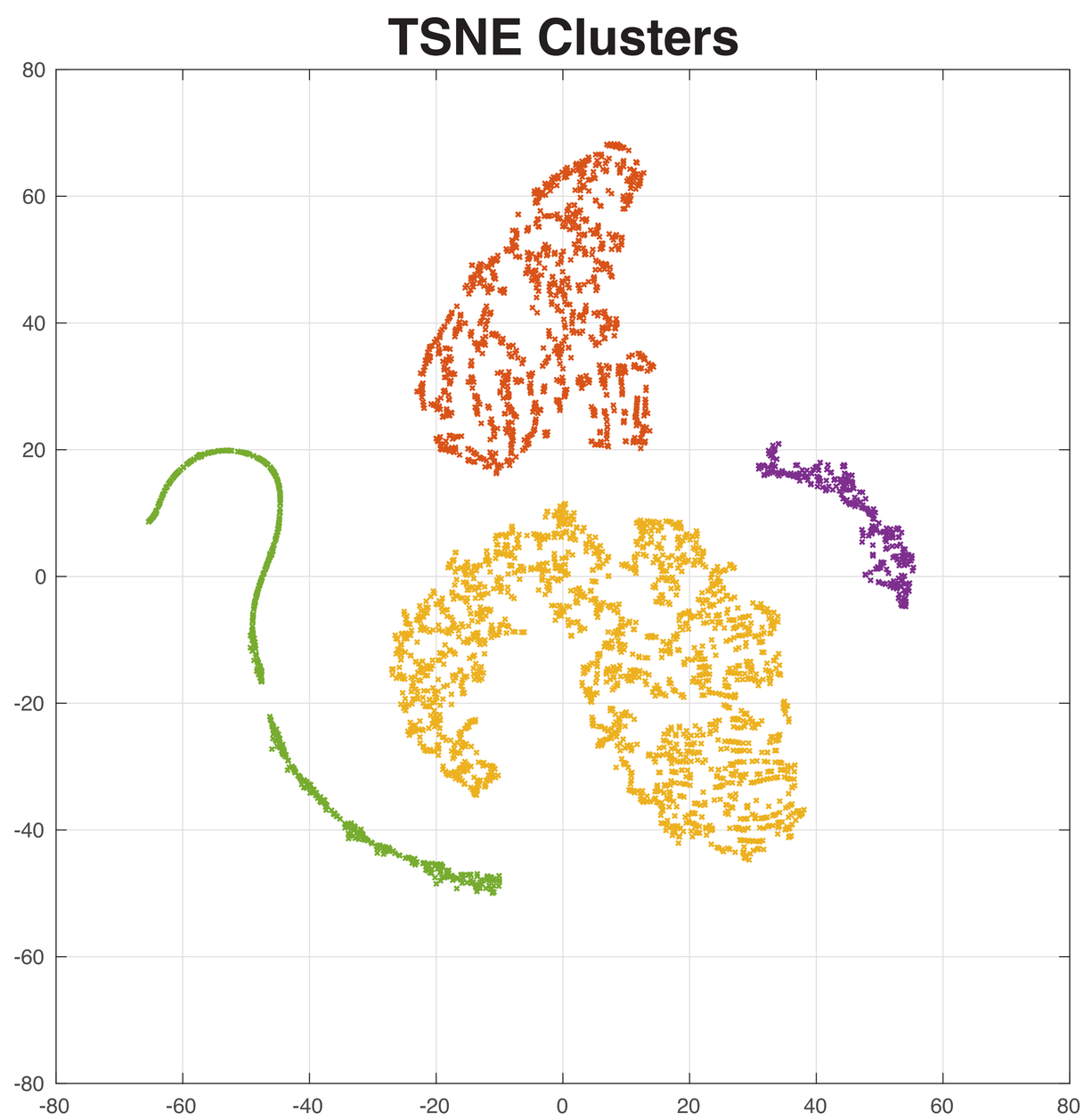

Figure 2: TSNE and DBSCAN indicate the 4 distinct lesion classes shown above. Each point represents an individual lesion. Axes are arbitrary values.

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Looking west from Whitetooth Mountain, into Glacier National Park in Canada