A New MRI Texture Measure to Quantify MS Lesion Progression

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Introduction

Accurate quantification of natural pathological changes in Multiple Sclerosis (MS) is critical for evaluating patients' therapeutic responses to clinical trials and monitoring disease development. Despite its heterogeneity in pathogenesis, MS generally has three distinct appearances on Magnetic Resonance Imaging (MRI): normal appearing white matter (NAWM), active lesion and inactive lesion. We believe that as NAWM becomes abnormal in MS, its "texture" in MR exams may change. Image texture, by definition, refers to the distribution of intensities within a local image region[1]. The local image intensities in turn will uniquely determine the local spatial frequency content. The polar S Transform (PST)[2] is a new local multiscale Fourier analysis that provides rotationally invariant Fourier spectral information around each pixel. Thus, the PST may be an ideal tool to examine MR texture. In this study, we utilized the PST to characterize texture changes in T2-weighted (T2w) MRI during MS lesion evolution.

Methods

Twenty untreated relapsing remitting MS patients were scanned bi-monthly for twelve months on a 1.5T Siemens 63SP MR System. 10/20 patients were selected based on the following criteria: they had an "active" MR scan (containing at least one new Gadolinium-enhanced lesion) in an area that was NAWM on the previous scan. Inactive lesions were selected from the fourth scan after the "active" scan. The MR protocol included a T2w fast spin echo sequence with the following parameters: TR/TE=2270/80ms, FOV=25cm, matrix size=256x256, slice thickness=3mm, with 3mm gap. All MR images were non-uniformity corrected using N3[3], then co-registered using 3D FLIRT[4] to align the sequential MRI for each patient. Twelve 32x32 pixel regions of interest (ROIs) were chosen from corresponding slices to evaluate the evolution from NAWM, to active then inactive lesions. The PST spectrum of each ROI was computed to generate a local 2D Fourier spectrum for each pixel. Each local 2D spectrum was then reduced to a local 1D spectrum by integrating it along rings of constant width (0.32 cycles/cm) in the Fourier domain. The local 1D spectra from the central 5x5 pixels in each ROI were averaged and normalized for analysis. The sum of low frequency energy (sumLFE) was calculated as the area under a distribution spectrum within a certain frequency range ($0<f<=2.88$ cm^{-1}). Finally, a Student's t-test was used to evaluate texture changes from NAWM, to active then inactive lesion with confidence level $\alpha=0.05$ as significant.

Results

There was obvious difference in the spectral distribution pattern among NAWM, active and inactive lesion (Figure 1). The low frequency contents (coarse texture) in active lesion increased (arrow) compared to NAWM. It decreased slightly in inactive lesion, but was still higher than in NAWM. Differences in their higher frequency contents (fine texture), however, were minor. Interestingly, all patients had very similar spectral distributions. Figure 2 displays the mean and standard deviation of sumLFE in NAWM, active and inactive lesions from all twelve ROIs. The mean sumLFE in active and inactive lesions increased by 31.1% and 11.9% respectively compared to NAWM. Most importantly, the low frequency difference was statistically significant between NAWM and active lesion ($p=0.00035$), NAWM and inactive lesion ($p=0.0012$) and between active and inactive lesion ($p=0.0069$).

Conclusion

The local spectral distribution at low frequencies ($f <= 2.88$ cm^{-1}) changed markedly during MS lesion development. The low frequency energy was significantly increased in active lesions compared to the prior NAWM, and subsequent inactive lesions. There was also a significant difference in low frequency energy between NAWM and inactive lesions. This study suggests that PST analysis has potential to evaluate therapeutic responses from MS patients in clinical trials and to predict lesion activity on T2w MRI.

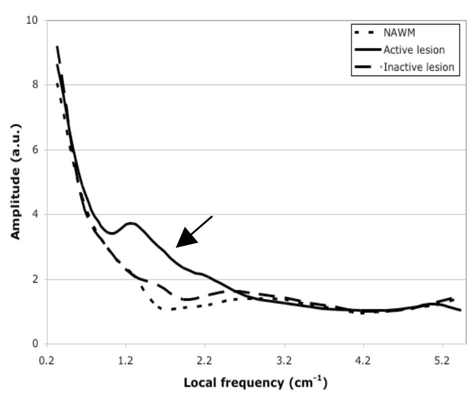

Fig. 1: An example of the averaged local 1D spectra in one ROI evolution from NAWM, to an active then an inactive lesion. There was large difference in their low frequency contents (arrow)

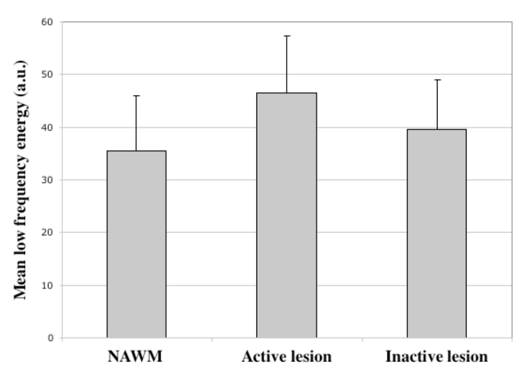

Fig. 2: The means of the low frequency energy ($f<=2.88$ cm^{-1}) in NAWM, active lesion and inactive lesiosn from all ROIs. The bars show the standard deviation in each group

References

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