

MRI texture correlates of pathological findings in post-mortem multiple sclerosis brain

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Introduction

Texture analysis has the potential to detect subtle alterations in image signal that are invisible on conventional MRI. Measures of texture are hypothesized to represent unique signatures of the tissue that generates the signal. The polar Stockwell transform (PST) is a spatial-frequency based texture analysis technique that combines features of Fourier and wavelet transforms.¹ The PST provides rotationally invariant, multiscale Fourier information around each pixel.² PST studies *in vivo* showed that lesions with gadolinium enhancing activity in multiple sclerosis (MS) contain greater coarse texture than the normal appearing white matter (NAWM), and lesions without enhancement indicating higher tissue heterogeneity.³ Furthermore, demyelination and inflammation produce larger PST texture in murine mouse than controls animals.⁴ The goal of this study was to validate PST analysis as a potential measure of tissue integrity using post-mortem samples from individuals with proven MS.

Method

Ten brain samples were examined from 3 subjects [2 female, 1 male; mean age=36 years (ranges 24-49); mean disease duration=13 years (ranges 8-20)]. Each sample was sectioned into 1-cm thick slabs along coronal or transverse planes and individually packed into formalin filled plastic containers. Ten slabs of interest were chosen as per MRI discrimination. Selected 1-cm samples were then imaged on a 7T Bruker Avance MR scanner (Ettlingen, Germany) using a multi-echo T₂ sequence: matrix=256x256, FOV=6 cm, in-plane resolution=234x234µm, slice thickness=1 mm, TR=1500 ms, echo spacing=6.6 ms, 32 echoes. Finally, the imaged samples were paraffin embedded and cut into 10-µm sections along the surface of interest. Luxol fast blue (LFB) staining for myelin and Bielschowsky staining for axons were applied. Histological images were registered to the MR images using Image Pro Plus and sections matching the center of MRI slices were used for comparison.

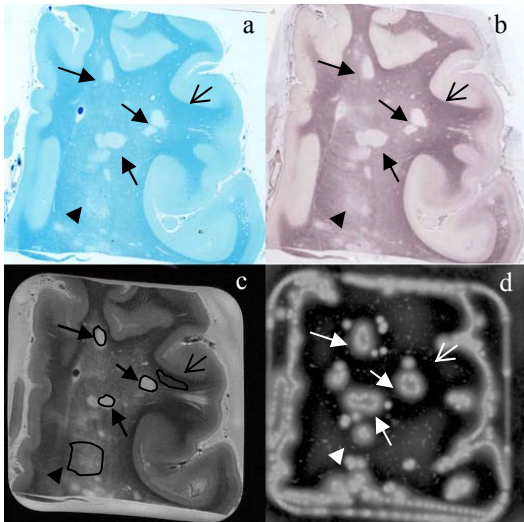


Fig1: A texture map (d) derived from the MR image (c) demonstrates equivalent pathological changes as observed in myelin and axonal staining (a, b). ROIs outlined in (c) indicate: lesion: \blacktriangledown ; rLrB: \blacktriangleright ; NAWM: \blacktriangledown .

The rLrB texture was greater than the NAWM ($p < 0.01$) (Figure2).

Discussion

This histology driven validating study showed that tissue texture was the highest in lesions, intermediate in areas with rLrB and lowest in NAWM, which may indicate that tissue with greater demyelination and axonal injury causes larger texture heterogeneity. This finding is consistent with a previous animal study.⁴ PST is an analysis that provides an image-wide frequency spectrum around each pixel. This capability allows for the characterization of pathological changes that are known to be heterogeneous in MS.⁵ Indeed, evolving texture activity was identified in MS lesions that were undetected on conventional MRI.⁶ This study provides evidence that texture analysis using the PST could be a new strategy to quantify tissue integrity in MS and possibly other neurological disorders.

References

- [1] Stockwell R.G. et al. IEEE Trans Signal Process. 1996; 44, 998-1000. [2] Zhu H, et al. METMBS proceedings. 2004. [3] Zhang Y, et al. NeuroImage 2009; 47: 107-11. [4] Zhang Y, et al. Lecture Notes in Computer Science. 2006;4190:760-767. [5] Compston A. et al. Lancet 2008; 372: 1502-17. [6] Zhang Y, et al. 16th ISMRM proceedings. May 2004.

A neuropathologist marked regions of interest (ROIs) on histological sections including areas of no LFB and markedly reduced Bielschowsky staining (lesions), mildly reduced LFB and Bielschowsky staining (rLrB), and normal staining (NAWM). These markers were used as a reference for determination of MRI ROIs. PST texture was calculated for each pixel in a ROI. A texture map was computed as differences of image texture than that of the intramural NAWM. Average texture of each ROI was extracted from the map. Tissue texture was assessed using one-way ANOVA followed by a Bonferroni correction ($p \leq 0.05$ was set as significant).

Results

Fourteen lesions, 19 rLrB, and 12 NAWM ROIs were identified on MR images from 10 brain sections. Tissue ROIs were variable in size and number per sample. ROI shape was arbitrary. Texture maps of individual MRI slices corresponded well visually with the paired histopathological slices (Figure1). Texture differences between lesion, rLrB, and NAWM regions were statistically significant ($p < 0.01$). Specifically, lesion texture was higher than that of rLrB and NAWM ($p < 0.01$) (Figure2).

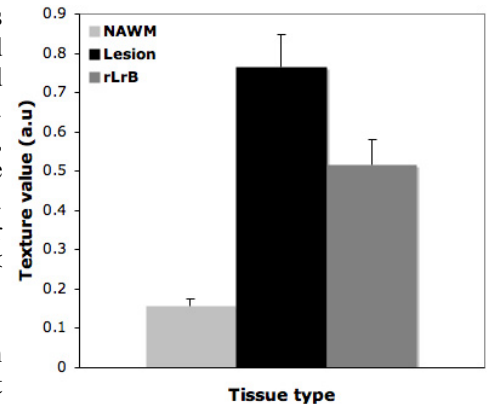


Fig2: Mean (standard error) texture in lesions was the greatest as compared to that in areas of rLrB ($p < 0.01$) and NAWM ($p < 0.01$).