

Prediction of persistent and transient T1 'black holes' in multiple sclerosis using MRI texture analysis

Y. Zhang¹, A. Traboulsee¹, Y. Zhao¹, L. M. Metz², and D. K. Li³

¹Department of Medicine, University of British Columbia, Vancouver, British Columbia, Canada, ²Department of Clinical Neurosciences, University of Calgary, Calgary, Alberta, Canada, ³Department of Radiology, University of British Columbia, Vancouver, British Columbia, Canada

Introduction

New contrast-enhancing lesions (CELs) in multiple sclerosis (MS) are frequently accompanied by hypointensity on T1-weighted MRI, so called acute T1 black holes (BHs). An acute T1 BH either persists as a permanent BH (persistent BH, trueBH) or evolves over time into an isointense lesion (transient BH, tranBH). While a trueBH is thought to represent irreversible tissue destruction, the evolution of a tranBH likely parallels remyelination.^{1,2} Remyelinated lesions may help to ensheath the denuded axon and thereby assist to restore compromised CNS function. However, tranBHs and trueBHs when first seen as an acute T1 BH appear similar on conventional MRI³ and are difficult to differentiate *in vivo*. MRI texture analysis using polar Stockwell transform (PST) shows promise for detecting subtle abnormalities in signal intensity and pattern.⁴⁻⁵ Preliminary work suggests that the PST may be a useful tool to quantify texture differences between tranBH and trueBH on T1-weighted MRI in MS.⁶⁻⁸

Method

Twenty relapsing-remitting MS patients were scanned at baseline and at month 9 in a clinical trial testing the add-on effect of minocycline to glatiramer acetate for MS therapy. Pre- and post-contrast T1-weighted MRI and T2-weighted scans were acquired with a GE 3T system. An experienced neuroradiologist identified new CELs that were simultaneously hypointense on the pre-contrast T1 scan at baseline. These lesions had to be normal appearing white matter (NAWM) on T2-weighted MRI one month before onset. An acute T1 BH was classified as a trueBH or a tranBH based on its appearance at the month 9 T1-weighted MRI. NAWM tissue from the same patient population at baseline was evaluated for control. The T1 texture of NAWM was averaged from regions of bilateral frontal lobes.

T1-weighted MRI was non-uniformity corrected and 3D co-registered serially. Regions of interest (ROIs) were drawn around each BH at baseline and were superimposed to the registered MRI at month 9 to ensure evaluation of the same region over time. PST texture was calculated for each pixel in a ROI. Averaged PST spectrum from central 5x5 pixels of a ROI were utilized for analysis. Texture difference was assessed using multivariate regression analysis. $P \leq 0.05$ was set as significant.

Results

There were 15 acute BHs (8 trueBHs and 7 tranBHs) identified from 9 MS patients. Nine NAWM regions were obtained. Different local spectra were found between T1 BHs and NAWM ($P = 0.02$) particularly over low frequency ranges. Unlike the smoothly decreased frequency distribution pattern exhibited in NAWM ROIs, focal magnitude increases were observed in T1 BHs, which span broader and are of higher energy in trueBHs than that in tranBHs (Figure 1). Furthermore, the spectral energy over low frequencies was significantly greater in the trueBH than that in the tranBH ($P < 0.05$) (Figure 2), with both being larger than in the NAWM. The high frequency spectrum did not differ between the groups ($P > 0.05$).

Discussion

This preliminary study showed that low frequency energy representing coarse texture was greater in the trueBHs than that in the tranBHs at the time of active lesion (CEL) formation, nine months before the acute black hole had evolved into its final state. It may indicate that trueBHs contain more severe tissue damage and therefore higher structural heterogeneity than the tranBH, and in contrast to the focal plaque-free NAWM where structural integrity is relatively preserved. This greater tissue complexity at the time of lesion formation in trueBH may have confounded its reparative ability compared to tranBH. Indeed, a previous study has shown that larger low frequency energy at lesion onset is related to poorer recovery 8 months later.⁷ The potential for texture analysis to predict trueBHs from tranBHs at lesion onset in MS may be very useful for a more precise quantification of lesion activity and accurate evaluation of therapeutic efficacy aimed at neuroprotection or repair.

References

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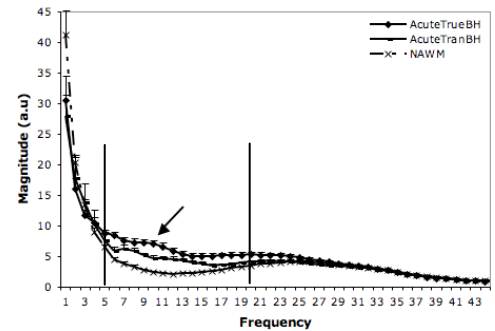


Fig1: Mean (stderr) frequency energy in trueBH, tranBH, and NAWM of MS patients. Low frequency (block) was higher in acute T1 BHs than in NAWM.

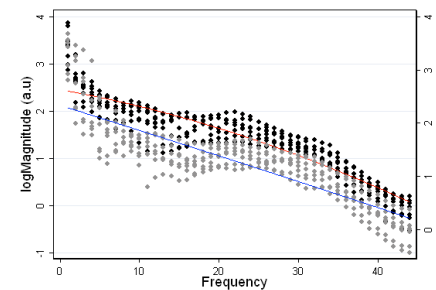


Fig2: Scatter plot of log magnitude of trueBHs (black dots) and tranBHs (gray dots). The q fit of trueBHs (red) was higher than that of tranBHs (blue) ($P < 0.05$).