Tissue Similarity Map of Perfusion Weighted MR Imaging in the Study of Multiple Sclerosis

E. M. Haacke[1], M. Li[1], and F. Juvvigunta[1]
[1]Department of Radiology, Wayne State University, Detroit, Michigan, United States

Introduction:

Multiple Sclerosis (MS) is a chronic inflammatory demyelinating disease of the central nervous system. It has been shown that cerebral perfusion in MS is reduced with the function of severity of the disease [1-3]. The purpose of this study is to use a new approach to processing PWI data that we refer to as Tissue Similarity Maps (TSM) to identify those lesions linked by the same vascular response to the contract agent [4]. TSM can investigate the differences in perfusion between any two tissues. It is created by selecting a reference region for a given tissue of interest and comparing its signal in a mean squared error (MSE) sense to the signal from every pixel in all images acquired with PWI. Here the reference region is chosen to be the MS lesion with the goal of finding out what other tissues whether MS lesion or not behave the same way. If two tissues have low MSE values then we assume that they behave the same.

Materials and Methods:

Ten MS patients were scanned on a 1.5 T Scanner (Siemens, Erlangen, Germany) with an 8 channel head coil. Parallel imaging was used with GRAPPA and an acceleration factor of 2. The patients were administered with a contrast agent Gadolinium-DTPA with a dosage of 0.1mmol/kg of body weight. A total 50 measurements were acquired over 110 seconds. A high resolution PWI GE-EPI sequence was used with TR/TE = 2200/98ms, FA = 60°, FOV = 256mm x 256mm, acquisition matrix was 256 x 256 but interpolated to 512 x 512, TH = 4mm with 4mm gap. FLAIR data were also collected with: TR/TE = 9970/72ms, TI = 2500ms, FA = 150°, FOV = 256mm x 256mm, and TH = 4mm with 0.4mm gap. T1 SE scans were collected with: TR/TE = 607/13ms, FA = 90°, FOV = 256mm x 256mm, and TH = 4mm. Data analysis was done using our home built SPIN (Signal Processing in NMR) software (Detroit, Michigan). To develop TSM from PWI, a region of interest (ROI) was selected and used as a reference input function $S_{ref}(t)$. Then the mean squared error (MSE) was calculated from $S_{ref}(t)$ and from all other pixels $S(t)$ through the following equation:

$$MSE(\vec{r}) = \sum_{i=1}^{n} (s(\vec{r}, (t_i - \Delta ttp)) - s_{ref}(t_i))^2$$

where Δttp is the difference of time-to-peak (TTP) between the pixels under investigation and the reference ROI. In this study the reference ROI was drawn on a given MS lesion on the high resolution PWI image and processed to yield that TSM image which should null lesions. The cerebral blood volume (rCBV) was calculated from the area under the concentration time curve.

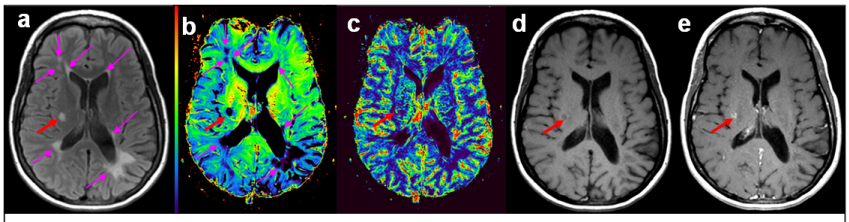


Figure 1: MS lesions for subject 1. a)FLAIR; b) TSM-nulling lesion; c) rCBV; d) pre-contrast T1 weighted Imaging; e) post-contrast T1 weighted imaging. The pink arrows point the chronic lesions in FLAIR (a) and TSM (b). The lesion pointed by red arrow is acute as seen enhanced in post-contrast T1 (e).

Results and Discussion:

The TSM-nulling lesion image has high signal-to-noise ratio (SNR). We drew the ROI within one random MS lesion. However the TSM-nulling lesion images picked up both chronic lesions and acute lesions throughout the brain (Figure 1). The FLAIR image (1a) shows several hyperintense MS lesions in the white matter and some around the ventricle. In the post-contrast T1 image one gadolinium-enhancing lesion indicated by the red arrow can be found in (1e). The lesions in the TSM (1b) have similar shape and size when compared to FLAIR (1a). As the lesions are not clearly seen in rCBV maps, now with the help of the TSM-nulling lesion image, we can easily draw the boundary of the MS lesion and copy it to rCBV maps for comparison. Graph 1 shows the rCBV comparison between normal white matter and lesions for the same patient showed in Figure 1. rCBV for the normal WM was 8.47 ml/100g tissue. Among the 11 MS lesions, 10 of them were chronic lesions and showed less perfusion. The average rCBV for these ten lesions was 4.05 ml/100g tissue. It reduced 52%. However the acute lesion (red arrow indicated in Figure 1) has higher rCBV than the normal white matter. It had roughly a 30% increase in rCBV. TSM-nulling lesions also showed some structures of interest in the brain. In Figure 2, the caudate nucleus, globus palidus, putamen, thalamus and corpus callosum are clearly shown and with well differentiated with good contrast.

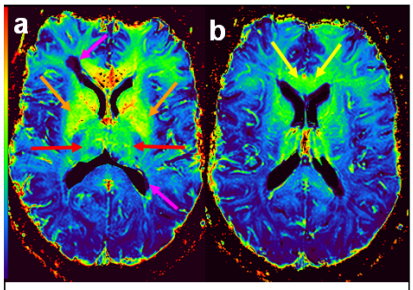
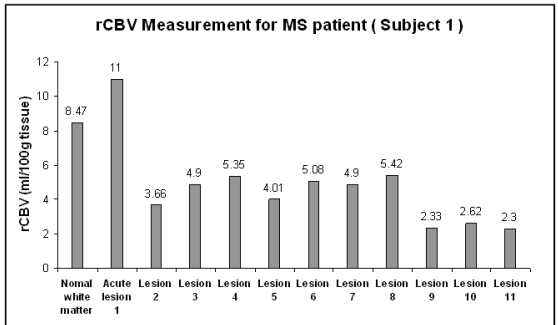


Figure 2: TSM-nulling lesion for subject 4. The slices showing finite brain structures:
pink arrows: MS lesions; orange arrows: caudate nucleus, globus palidus and putamen; red arrows: thalamus; yellow arrows: corpus callosum.



Graph1: rCBV comparison between normal WM and MS lesions of subject 1. All lesions had less rCBV than normal WM except one acute lesion.

Conclusion:

The TSM of nulling the MS lesions is successful in enhancing specifically MS lesions, no matter which lesion is chosen as the reference ROI. Tissue similarity maps are a very useful means to reveal information about tissues otherwise difficult to see with conventional PWI processing approaches. It plays an important role in validation and diagnosis of the vascular similarities between diseases, such as multiple sclerosis, stroke or tumor.

Reference:

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