MR Signal Fluctuations and Regional Vasomotion

H. Pien[1], W. Zhang[1], E. DiTomaso[2], D. Duda[3], R. Jain[2], T. Batchelor[4], and A. G. Sorensen[1]

[1]Radiology, Massachusetts General Hospital and Harvard Medical School, Boston, MA, United States, [2]Radiation Oncology, Massachusetts General Hospital and Harvard Medical School, Boston, MA, United States, [3]Radiation Oncology, Massachusetts General Hospital and Harvard Medical School, Bosotn, MA, United States, [4]Neurology, Massachusetts General Hospital and Harvard Medical School, Boston, MA, United States

Problem. Fluctuations in MR signal intensity of the resting brain is believed to be related to vasoconstrictive physiological motion; such fluctuations occur at a frequency far lower than cardiac and respiratory motion (1). These synchronous oscillations have been found to be regionally correlated (e.g., the motor cortex), and may also related to disease (2,3). In this study we continue the analysis of vasomotion, and test the hypothesis that tumors – with their tortuous vasculature – have a lesser degree of synchronous vasomotion than other regions of the brain.

Methods. Subjects with brain tumors (glioblastoma multiforme) are scanned using a Siemens 3-Tesla MRI (Tim Trio, Siemens Medical Solutions, Malvern, PA). Dynamic susceptibility contrast (DSC) imaging is performed – a 75-mm slab of tissue is imaged using a dual-echo, combined gradient-echo and spin-echo echo planar sequence. Such a sequence permits the acquisition of two images after each 90-deg RF excitation: a gradient-echo image (TE: 34) and a spin-echo image (TE: 103). Each image is acquired 1.33-s apart, and has an in-plane resolution of 1.7-mm and through-plane resolution of 5-mm, producing a 128x128 matrix. Gd-DTPA is injected after 85-s of imaging, thus providing 63 baseline resting-state images. Additional channels of data, including pre- and post-contrast T1, are also acquired so that lesions can be accurately located and delineated.

For each time-series of images at a particular slice location, $f(x_i,y_j,z_k,t)$, we compute the low-pass filtered signal $f_{lp}(x_i,y_j,z_k,t)$. The low-pass filter is performed as a frequency-domain Butterworth filter of order-6 with a cutoff frequency of 0.2-Hz so as to eliminate the higher frequency components of the signal. For every voxel, we compute the vector correlation *C* using Matlab (The MathWorks, Natick, MA). More specifically, we compute

$$C_{avg} = \left\{ C\left[f_{lp}(x_i, y_j, z_k, t), f_{lp}(x_{i-1}, y_j, z_k, t) \right] + C\left[f_{lp}(x_i, y_j, z_k, t), f_{lp}(x_i, y_{j-1}, z_k, t) \right] \right\} / 2 .$$

That is, we obtain the low-passed signal correlation between a voxel and the voxel above, the correlation between a voxel and the voxel to its left, and take an average of the two correlation values. The result is a local measure of the degree of similarity of the low-frequency signal intensity fluctuation between a voxel and its neighbors.

A simple intensity threshold is used to mask portions of the background, sinus region, and lateral ventricles.

Results. Several time series datasets are examined. Figure 1 shows a representative T1 post-contrast image, the corresponding gradient echo image that is the lead image of an 85-s resting-state baseline series, and the vasomotion similarity map for that series. Note that the tumor region appears to show synchronous vasomotion, and that other regions of such similarity can also be seen.

Conclusions. The correlation-based vasomotion similarity measure appears to contradict our hypothesis that tumor regions would be highly asynchronous; in fact it appears to be one of the most synchronous regions. Other regions of the brain can be seen to have highly synchronous vasomotion, although CSF pulsatile flow near the ventricles may account for some of the observed regions of high correlation. We have examined three subjects using this technique, and comparable similarity maps are observed with all three subjects. This technique appears to hold promise for further studies of low-frequency vasomotion of different regions of the brain.

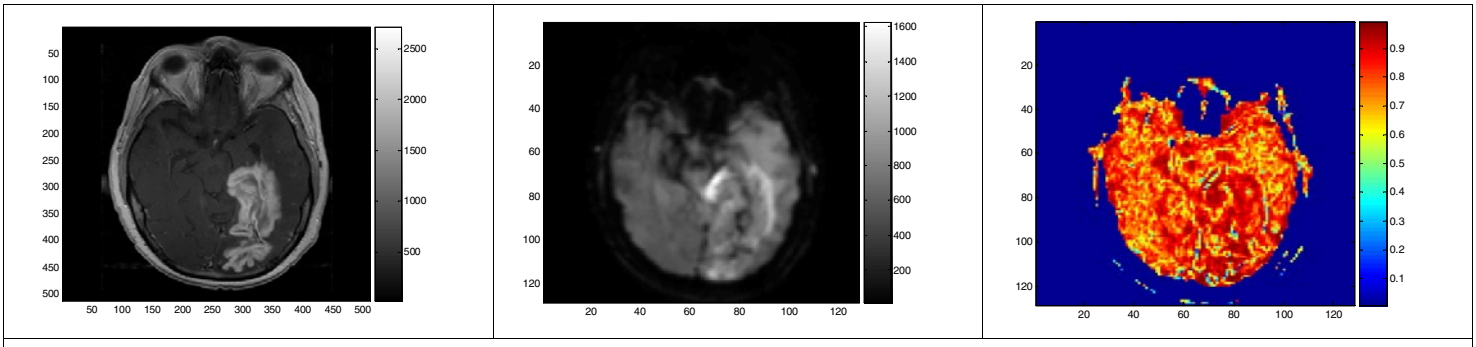

Figure 1. A T1 post-contrast image of a patient with GBM (left); the corresponding gradient echo image (mid), and the resulting vasomotion similarity map (right).

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References

1. Biswal B, Yetkin FZ, Haughton VM, Hyde JS. Functional connectivity in the motor cortex of resting human brain using echo-planar MRI. Magn Reson Med 1995;34(4):537-541.
2. Biswal BB, Van Kylen J, Hyde JS. Simultaneous assessment of flow and BOLD signals in resting-state functional connectivity maps. NMR Biomed 1997;10(4-5):165-170.
3. Buckner RL, Snyder AZ, Shannon BJ, LaRossa G, Sachs R, Fotenos AF, Sheline YI, Klunk WE, Mathis CA, Morris JC, Mintun MA. Molecular, structural, and functional characterization of Alzheimer's disease: evidence for a relationship between default activity, amyloid, and memory. J Neurosci 2005;25(34):7709-7717.