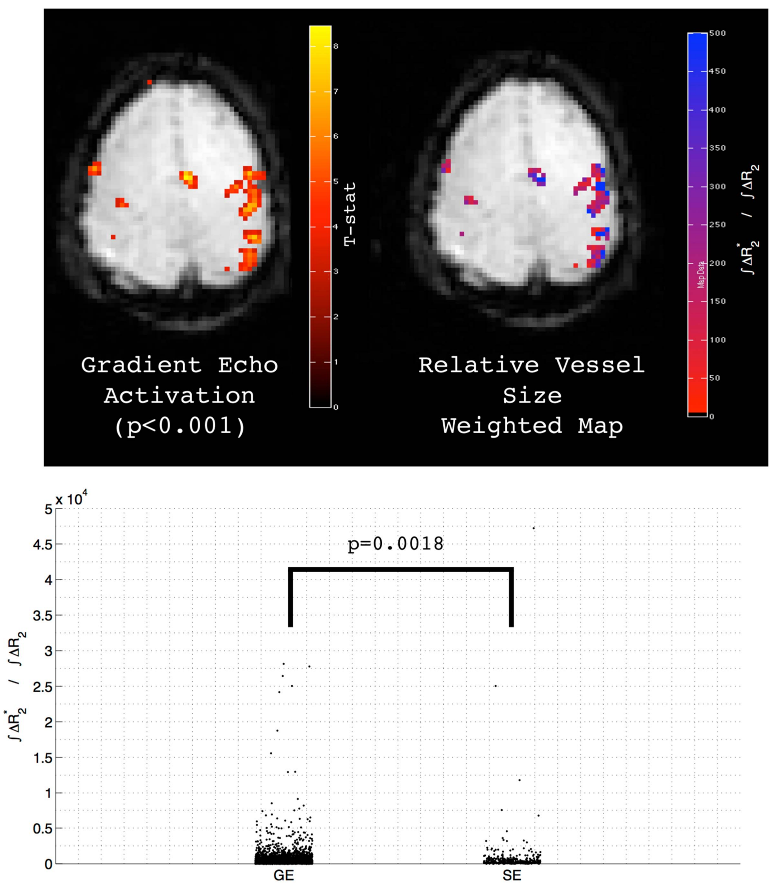
Mapping of Relative Vessel Sizes in fMRI With SAGE

Allen T Newton[1,2], Jack T Skinner[1,2], and C Chad Quarles[1,3]
[1]Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States, [2]Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States, [3]Institute of Imaging Sciences, Vanderbilt University, Nashville, TN, United States

[Target audience] Anyone interested in measuring vascular properties of tissue underlying typical BOLD fMRI activations or simultaneous spin echo and gradient echo acquisitions

[Purpose] It has been long since established that T_2 contrast mechanisms decrease sensitivity to fMRI activations in large draining vessels, at the cost of overall decreased sensitivity in capillary beds as well, however it has been suggested that simultaneous measurements of spin echo (SE) and gradient echo (GE) images may provide the ability to obtain more continuous vessel size information[1]. Our motivation for this study was to take advantage of emerging simultaneous spin and gradient echo (SAGE) acquisition[2] schemes to dynamically image SE and GE BOLD changes, such that their ratio might provide a method to measure the relative vessel size information underlying traditional gradient echo fMRI experiments, allowing future studies to maintain improved sensitivity characteristic of GE acquisitions while leveraging the specificity of SE signal changes to the capillary component of the underlying vasculature. **[Methods]** Five subjects were imaged at 3T using an eight channel receive array and a SAGE pulse sequence (FOV=220x220x80mm, #slices=20, θ=90°, TR=2s,partial fourier=0.74, SENSE=2, vox.vol.=3.44x3.44x4.0mm, 90volumes). Only the second and fifth echos were considered for this study, corresponding to the GE and SE images typical for fMRI studies (TE=22.5/-0.5ms and 71ms respectively). Subjects were asked to complete a traditional finger tapping task ({left 2s, right 20s, rest 20s}x3). All images were corrected for slicing timing artifacts and motion artifacts using SPM8. ΔR^*_2 and ΔR_2 time courses were calculated by: $\Delta R_2^{(*)}=-\ln(S_t/S_{rest})/TE$. For all subjects, the relative vessel size weighted ratio (rVSW) $\int \Delta R^*_{2,\text{task}} / \int \Delta R_{2,\text{task}}$ was calculated for both left and right hand finger tapping conditions, and the maximum value between the two was kept for each voxel. To test whether this ratio was indeed sensitive to underlying vessel sizes, this ratio was compared in voxels identified as being significantly active in SE data to those voxels significantly active in simultaneously acquired GE data. Activation maps were created identifying all voxels significantly activated at the individual subject level ($p<0.001$unc, no minimum cluster size) for both the SE and GE images. rVSW ratio measures were compared for differences between GE and SE active voxels across subjects using an unbalanced 2-way ANOVA with factors for contrast type and subject. **[Results]** In all subjects, significant activation to the finger tapping task was measured in both SE and GE images, an example of which is seen in Figure 1. rVSW ratio maps in each subject show higher values near the surface of the brain as well as overlapping some (though not all) particularly strong activations in the GE data, suggestive that those particular strong activations overlie larger venous structures. The ANOVA showed significant differences in the rVSW ratio measured in voxels activated in GE data as compared to those activated in SE data, providing further support that this metric is sensitive to differences in underlying vascular sizes. **[Discussion]** Here, we have shown that SAGE acquisitions can be used for fMRI studies to obtain information about the size of vessels underlying typical gradient echo activations. While these data support the role that vessel size plays in the rVSW ratio, it is important to note that other factors may play a role as well, including changes in underlying oxygenation, and this effect needs further study.



[References] (1) Bandettini et al. Simultaneous Mapping of Activation – Induced ΔR_2^* and ΔR_2 in the Human Brain Using a Combined Gradient-Echo and Spin-Echo EPI Pulse Sequence. New York, NY: 12th Annual Meeting of the International Society for Magnetic Resonance in Medicine; 1993.(2) Schmiedeskamp et al. Simultaneous perfusion and permeability measurements using combined spin- and gradient-echo MR. Journal of Cerebral Blood Flow & Metabolism (2013) 33, 732–743.
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Figure 1: (top right) A typical gradient echo activation map to the finger tapping task. (top right) A map of the rVSW ratio which is partly proportional to underlying vessel size and oxygenation changes. Note the increase in the ratio near the surface of the brain, and coinciding with especially strongly activated voxels, suggestive that these voxels indeed overlay larger draining vessels. (bottom) Scatter plots of the ratio of rVSW ratio in voxels significantly activated in GE and SE images across all subjects. ANOVA results show a significant difference between voxels showing SE activity verses GE activity in terms of the rVSW ratio.