ANALYSIS OF THE SPIN AND GRADIENT ECHO (SAGE) SEQUENCE FOR DSC-MRI IN RAT BRAIN TUMORS

Ashley M Stokes[1,2] and C. Chad Quarles[1,2]

[1]*Institute of Imaging Science, Vanderbilt University, Nashville, TN, United States,* [2]*Radiology and Radiological Sciences, Vanderbilt University, Nashville, TN, United States*

Target Audience: This study is targeted toward researchers interested in the development of advanced perfusion imaging methods.

Purpose: A combined spin- and gradient-echo (SAGE) EPI method (1,2) was recently proposed to simultaneously obtain absolute ΔR_2, ΔR_2^* and ΔR_1 curves, thereby permitting derivation of dynamic susceptibility contrast (DSC) parameters, including cerebral blood volume (CBF) and flow (CBV), mean transit time (MTT), and vessel size images (VSI) and the DCE-MRI parameters, K^{trans} and v_e. Previous human studies were performed in stroke and tumor (2). This study focuses on optimization and application of the SAGE sequence in a preclinical model of rat glioma. Partial Fourier encoding is used to reduce the echo times to less than 100 ms for all five echoes. Using this sequence, T_1-insensitive estimates of R_2 and R_2^* can be acquired using all five echoes and compared to conventional DSC parameters using only the 2nd and 5th echoes (GE and SE, respectively). Moreover, the SAGE-derived R_2 and R_2^* at baseline (pre-contrast) can be compared with conventional methods for measuring R_2 and R_2^* (pre-contrast).

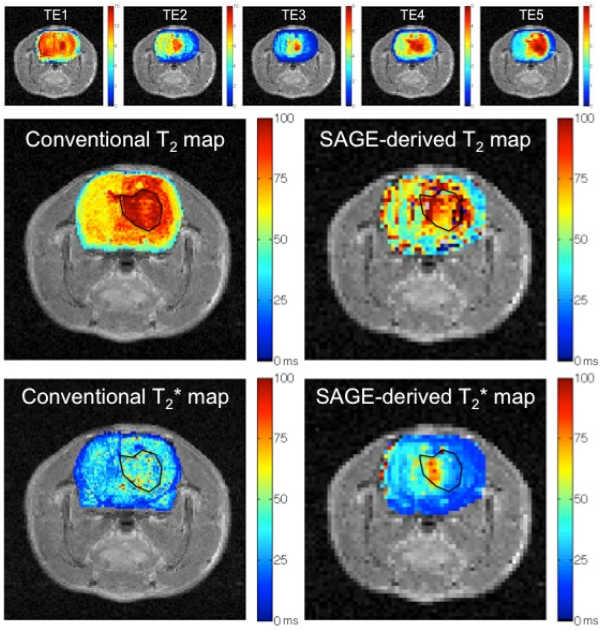

Figure 1: Comparison of conventional T_2 and T_2* maps with SAGE-derived T_2 and T_2* maps.

Methods: C6 glioma cells were implanted in Wistar rats, and MRI was performed at 4.7T (Agilent) after 20 days. Pre-contrast T_2 and T_2^* maps were acquired using conventional techniques (T_2 – multiple spin-echo sequence: TR=3s, TE=9ms, ΔTE=9ms, NE=18; T_2^* – 3D multi-gradient-echo sequence: TR=100ms, TE=2.82ms, ΔTE=3.4ms, NE=20). The SAGE-EPI sequence with partial Fourier encoding (44 of 64 lines acquired) was used to obtain five echoes (TR = 1s, TEs = 7.5/34.1/60.1/86.6/96.5ms, 500 repetitions). After 60s of baseline images, 2 mmol/kg Gd-DTPA was injected via a jugular catheter. The SAGE derived R_2 and R_2^* curves were obtained using least squares fitting of a piecewise function as previously described (2).

Results: Figure 1 (top row) shows the five echoes obtained pre-bolus using the SAGE sequence. Using the pre-contrast SAGE data, we derived T_2 and T_2^* maps (right column) and compared them to conventional T_2 and T_2^* maps (left column). Figure 2 shows the ΔR_2^* and ΔR_2 curves for GE (2nd echo), SE (5th echo), R_2^* (SAGE fit), and R_2 (SAGE fit) in normal brain and tumor. Using the ΔR_2^* curves, rCBV maps were created using the GE data and SAGE fits.

Discussion: The T_2 maps are qualitatively similar, showing higher T_2 in the tumor region compared to normal brain. The T_2^* maps show greater differences between conventional and SAGE techniques, most notably on the right side of the brain. This may be due to poor SAGE data fits in this region and can be traced to susceptibility induced signal losses in the 2nd and 3rd echoes. Care was taken in subsequent analyses to avoid regions with poor SAGE fits. In the DSC curves, the normal brain GE ΔR_2^* curve produced similar, although slightly underestimated, rCBV values (obtained from the area under the curve) compared to the T_1-insensitive SAGE R_2^*. In contrast, the tumor GE ΔR_2^* curve led to substantially underestimated rCBV values compared to the SAGE R_2^*, primarily due to leakage effects.

Conclusions: The SAGE sequence permits dynamic acquisition of multiple gradient and spin echoes that can be used to provide measures of perfusion and permeability in a preclinical setting. Future work will aim to characterize and improve signal quality, further shorten TE, and determine hemodynamic parameters in rat brain tumor models.

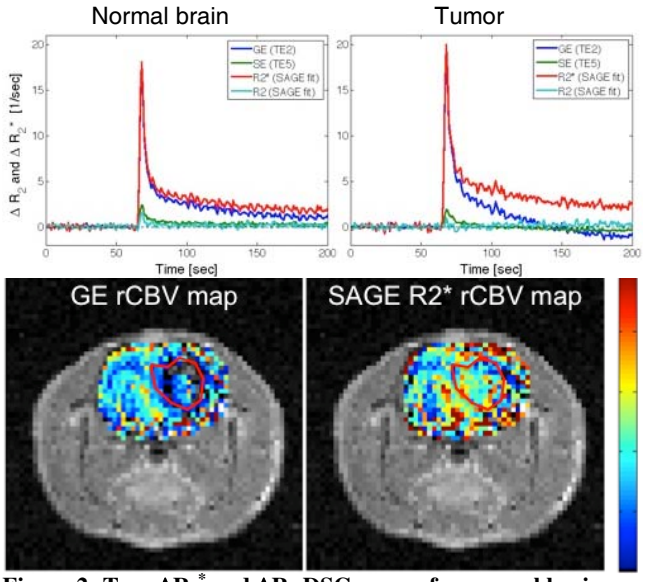

Figure 2: Top: ΔR_2^* and ΔR_2 DSC curves for normal brain and tumor. Bottom: GE and SAGE R_2^* rCBV maps.

References: 1. Schmiedeskamp H, et al. Magnetic Resonance in Medicine 2012;67(2):378-388. 2. Schmiedeskamp H, et al. Magnetic Resonance in Medicine 2012;68(1):30-40.