A Single-Shot Multiple Spin- and Gradient-Echo Acquisition for Perfusion Imaging Using SENSE Acceleration and Partial k-Space Sampling

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TARGET AUDIENCE: This study is aimed at those interested in advanced quantitative MRI methods for perfusion imaging.

PURPOSE: Previous techniques for cerebral perfusion imaging often include single-echo measurements using either gradient- or spin-echo acquisitions. These methods have also been extended to multiple gradient-echo sequences for the purpose of acquiring more accurate estimates of changes in R_2* with the introduction of contrast (1,2). Recently, a spin- and gradient-echo (SAGE) EPI acquisition was introduced, allowing simultaneous mapping of R_2 and R_2* (3). In this study we sought to implement a SAGE sequence that utilizes SENSE parallel imaging and partial k-space sampling in a single-shot acquisition. This combination allows short first echo times (< 10ms), suitable for arterial input function characterization in the context of quantitative perfusion imaging.

METHODS: The single-shot SAGE EPI sequence was implemented at 3T (Philips Achieva). The scan protocol included collection of 5 echoes (2 prior to refocusing) with TE = 8.4, 25, 52, 69, and 86ms at TR=1.8s, SENSE acceleration factor = 2, and k-space fraction = 0.77. The acquisition permitted collection of 15 slices with a 3.3 x 3.3 x 5 mm^3 voxel size and a 1mm slice gap. All reconstruction was performed on the scanner using the vendor's standard methods. To evaluate the current protocol, three $CuSO_4$ phantoms, with varying R_2, were imaged. In addition, a conventional multiple gradient-echo (MGE) measurement (TR=1.8s, non-EPI, TE= 2.5-75 ms, 30 echoes) and multiple spin-echo (MSE) measurement (TR=1.8s, non-EPI, TE=10-80 ms, 8 echoes) was acquired. Maps of R_2 and R_2* were created by least squares fitting of the SAGE data to signal equations previously described for a SAGE acquisition (3). For validation, similar maps were created by fitting the MGE and MSE data with monoexponential R_2* and R_2 decay functions, respectively. The previously described multi-echo acquisitions were also performed in the brain of a healthy volunteer to evaluate the current single-shot SAGE sequence *in vivo*.

Table 1. R_2 and R_2* values (mean ± s.d. in ROI) from multi-echo acquisitions in $CuSO_4$ phantoms.

	SAGE		MGE	MSE
Phantom	R_2	R_2*	R_2*	R_2
1	12.9±3.2	15.9±4.2	16.2±2.6	14.3±0.1
2	22.1±0.9	23.7±1.4	21.2±0.8	20.2±0.1
3	45.2±2.2	49.2±1.8	40.7±1.8	38.7±0.3

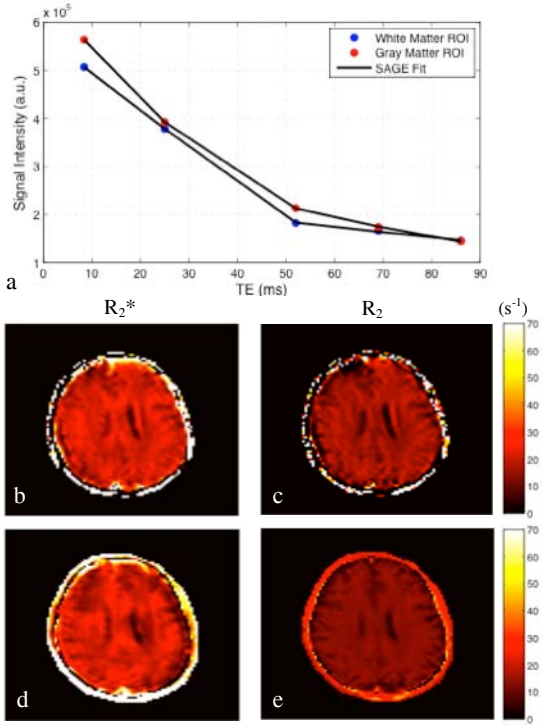

Fig 1. a) SAGE fit to decay data in GM and WM ROIs. R_2* maps from b) SAGE and d) MGE. R_2 maps from c) SAGE and d) MSE.

RESULTS: Mean values of R_2 and R_2* from the SAGE acquisition were within ~11% of those estimates from conventional MGE and MSE measurements in phantoms 1 and 2 (Table 1). Slightly larger differences in the values observed in phantom 3 are likely due in part to shorter T_2 and T_2* ($T_2 \approx$ 25ms) and the use of longer echo times in characterization of R_2 with SAGE. Fig. 1a shows qualitatively good fits to the SAGE data from ROIs in gray matter (GM) and white matter (WM). Measures of R_2 from the SAGE acquisition, in both GM and WM, tended to overestimate those values from MSE measurements (Fig. 1c,e). SAGE estimates of R_2* were found to be within 7% of the MGE data in the same ROIs (Fig. 1b,d).

DISCUSSION: In addition to further validation of the current technique, methods for compensation of possible slice profile mismatch are under investigation. In particular, the use of a wider refocusing slice profile is being considered in lieu of specialized RF pulses. The implementation presented here allows the trade-off of parallel imaging and partial k-space sampling for optimization of echo times and reduction of acceleration-based artifacts. Using the current protocol, dynamic acquisitions will be made in the presence of contrast to produce measures of both perfusion and permeability in brain tumor patients undergoing anti-angiogenic treatment.

CONCLUSION: The extension of a novel SAGE pulse sequence to a partial k-space acquisition with SENSE acceleration may provide a robust method for quantitative perfusion imaging.

REFERENCES: 1. Vonken E et al. MRM 2000; 43:820-827. 2. Newbould R et al. MRM 2007; 58:70-81. 3. Schmiedeskamp H et al. MRM 2012; 68:30-40.