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 been extended to multiple gradient-echo sequences for the purpose of acquiring more accurate estimates of changes in R2* with the introduction of contrast (1,2). Recently, a spin- and gradient-echo (SAGE) EPI acquisition was introduced, allowing simultaneous mapping of R2 and R2* (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 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 CuSO4 phantoms, with varying R2, 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 R2 and R2* 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 R2* and R2 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.

RESULTS: Mean values of R2 and R2* 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 to shorter T2 and T2* (T2 = 25ms) and the use of longer echo times in characterization of R2 with SAGE. Fig. 1a shows qualitatively good fits to the SAGE data from ROIs in gray matter (GM) and white matter (WM). Measures of R2 from the SAGE acquisition, in both GM and WM, tended to overestimate those values from MSE measurements (Fig. 1c,e). SAGE estimates of R2* 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.