Simultaneous Multi-Slice Spin and Gradient Echo Dynamic Susceptibility-Contrast Perfusion Imaging of Gliomas

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Highlights: SAGE DSC MRI allows to quantify perfusion parameters sensitive to both macrovessels and microvessels. However, the SAGE approach requires long acquisition time per each slice, which reduces spatial coverage. Here, we implemented SAGE EPI combined with SMS excitation to improve coverage, and performed SAGE DSC MRI to patients with gliomas.

Introduction: Dynamic susceptibility-contrast (DSC) MRI is a widely used technique to characterize first-pass hemodynamics in vivo following intravenous injection of a paramagnetic contrast agent. Derived tissue transverse relaxation-rate-change curves with high temporal resolution can be used to calculate perfusion parameters such as relative cerebral blood volume (rCBV), which is associated with increased tumor vascularity and histologic tumor grade. Combined multi-echo GRE and SE (SAGE) DSC MRI allows to quantify perfusion parameters sensitive to both macrovessels and microvessles while correcting T_1 leakage effects and to assess the vessel diameter, an additional measure of tumor angiogenesis. However, the SAGE approach requires long acquisition time per each slice to accommodate a long TE, which can sacrifice spatial coverage. In this work, we implemented three-echo SAGE EPI acquisition combined with simultaneous multi slice (SMS) excitation, blipped-CAIPI, and in-plane acceleration to provide both high temporal resolution and sufficient spatial coverage, and performed SAGE DSC MRI to patients with gliomas using two- or three-fold SMS acceleration for comparison.

Methods: A commercial version of GRE, blipped-CAIPI SMS EPI sequence was extended to enable the acquisition of a second GRE EPI train and a SE EPI train after the SMS refocusing pulse. DSC perfusion protocols with a multiband factor (MB factor) of two and three were applied to eleven patients with gliomas, respectively, using a GE 3T MR750 scanner and a 32 channel receive-only head coil. The imaging parameters included a 24 x 24 cm^2 FOV, 100 x100 matrix size, 3 mm slice thickness, in-plane acceleration factor of two, and $TE_1/TE_2/TE_3$=8.6/30/100 ms, 24/33 slices, 1.72/1.5 s TRs, and 70/80 temporal points (MB factor 2/3).

By using signal intensity time curves the three TEs, T_1-corrected relaxation-rate-change time curves ($\Delta R_2*(t)$ and $\Delta R_2(t)$) were derived. ΔR_2*-rCBV and ΔR_2-rCBV were quantified by fitting $\Delta R_2*(t)$ and $\Delta R_2(t)$ with a nonlinear gamma-variate model, and then normalizing by the mean values from NAWM for each subject. Mean vessel diameter (mVD) was calculated by measuring the ratio of the averaged ΔR_2* and ΔR_2 over the 15 s interval of the bolus passage.

Results: The first and second rows in Fig. 1 illustrate T_2w-FLAIR and post-contrast T_1w SGPR images, and ΔR_2*- and ΔR_2-rCBV, and mVD maps from two patients with contrast enhancing lesions (glioblastomas depicted by arrows) acquired with two different protocols. Both had similar contrast between NAWM and NAGM and demonstrated heterogeneity of different perfusion parameters within the lesions. The third row is from a patient with grade 3 oligodendroglioma, non-contrast-enhancing lesion with hyperintense on T_2w images. The regions of hypervascularity on both rCBV maps existed within the lesion, with yielding relatively low mVD.

Conclusions: SMS SAGE DSC perfusion MRI in patients with gliomas allows for quantifying perfusion parameters associated with both macrovessels and microvessels, affords extensive brain coverage, and provides enriched information about tumor vasculature compared to conventional GRE DSC perfusion MRI. The three-fold SMS acquisition provided image quality and perfusion quantification that was comparable to those with two-fold SMS acquisition.
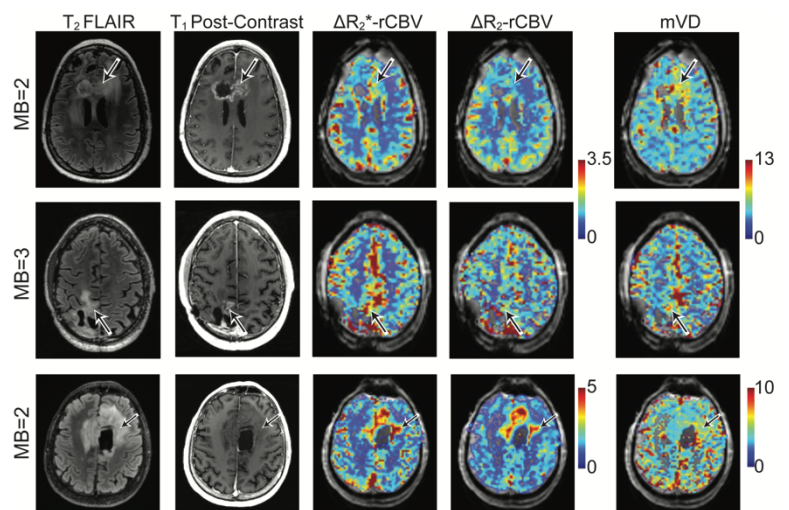

Figure 1. The first and second rows present perfusion quantification from two patients acquired with different MB factors. In the contrast-enhanced lesions (black arrows), ΔR_2*-rCBV was elevated compared to ΔR_2-rCBV and mVD was much higher than NAGM and NAWM. The third row is from a patient with a non-enhancing lesion (hyper-intense on T_2 FLAIR). The maps showed high ΔR_2*-rCBV and ΔR_2-rCBV in the lesion, and relatively lower mVD than lesions from the top two rows.