Slice Accelerated Spin and Gradient Echo (SAGE) Perfusion Imaging

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Target Audience: Researchers and clinicians who are interested in fast, whole brain Spin- and Gradient-Echo (SAGE) perfusion imaging.

Introduction: SAGE Perfusion-Weighted Imaging (PWI)[1] was recently developed in order to more robustly find perfusion parameters such as Cerebral Blood Flow (CBF) and Cerebral Blood Volume (CBV), as well as incorporate the ability to determine tissue leakage *in vivo*[2] in a clinically feasible sequence. These properties make it a very potent diagnostic tool, however, by acquiring both spin- and gradient-echo images, the echo and repetition times (TE/TR) are increased. This necessitates acquiring fewer slices with a longer TR than would be necessary for either spin- or gradient-echo imaging alone. Recent work in slice-accelerated (multiband) imaging[3-5] has shown that significant speedups are possible, especially when shorter TRs are desired. **This work demonstrates the application of simultaneous multi-slice imaging to SAGE PWI to allow whole brain coverage and accelerated temporal sampling.**

Methods: Volunteers: Two healthy normal volunteers were scanned with IRB approved written consent using the multiband SAGE perfusion sequence. Contrast: 20mL MultiHance (gadobenate dimeglumine) followed by 25mL saline were injected at 4.5mL/s 18s after the start of the acquisition. Acquisitions: Subject 1 was scanned with 24 slices (5mm thick, 1mm spacing, z-FOV=14.3cm), TR=1.5s, and 120 dynamic phases; subject 2 was scanned with 16 slices (6mm thick, 2mm spacing, z-FOV=12.6cm), TR=1s, and 192 dynamic phases. For both subjects, a 90° 2-band excitation pulse[6] (used to avoid exciting slices outside of the FOV) was followed by a 5-echo acquisition (TEs≈10, 27, 68, 84, 101ms) with the first 2 echoes before a 180° PINS pulse[7] and the remaining 3 after, with the final echo being a symmetric spin echo. The acquisitions were performed at 3T using a 32-channel head coil (Nova Medical, Wilmington, MA, USA). **Two slices were acquired simultaneously** with in-plane GRAPPA acceleration of R=3, matrix of 84x84, and in-plane FOV=24cm. Matching calibration scans without simultaneously acquired slices were used for ghost correction and GRAPPA calibration. Reconstruction: A SENSE-GRAPPA reconstruction[8] was implemented in-house in MATLAB. Processing: The arterial input function (AIF), calculated from the gradient-echoes[1], was manually selected in the left middle cerebral artery by an experienced researcher, and the perfusion analysis was performed in a home-built perfusion processing tool in MATLAB[9]. Note that the gradient-echo and spin-echo perfusion parameters displayed were calculated from R_2 and R_2* values derived from the multi-echo SAGE PWI dataset[1].

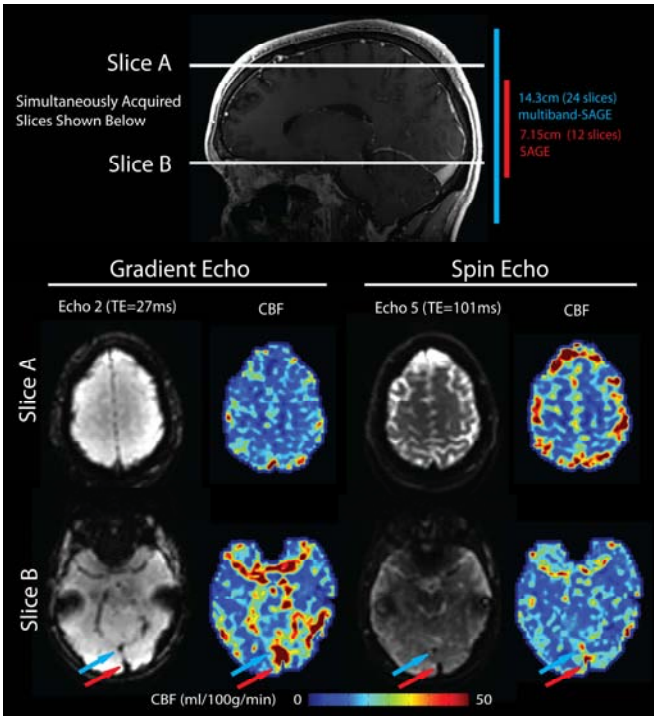

Figure 1: Subject 1 (24 slices, TR=1.5s) showing the z-FOV as well as the CBF from simultaneously acquired slices. Note that the signal blooming in the gradient-echo images causes an apparent merging of an artery (blue arrow) and a nearby vein (red arrow), while the spin-echo images keep the vessels distinctly separated.

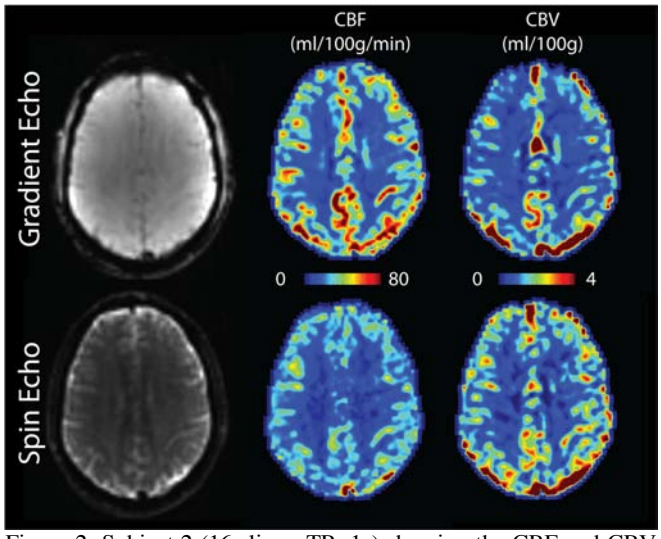

Figure 2: Subject 2 (16 slices, TR=1s) showing the CBF and CBV values from a single slice.

Results and Discussion: Figures 1-2 show the results from subjects 1 (TR=1.5s, 24 slices) and 2 (TR=1s, 16 slices), respectively. Note that in the gradient-echo CBF images (Figure 1, arrows) the vessels produced large signal blooming, an effect that is significantly reduced in the spin-echo CBF images. It is important to remember that these acquisitions are slice accelerated by a factor of two, which allows for whole brain coverage with 5mm thick slices as well as faster sampling rates (1.5 vs. 1.8s) than the previously proposed non-slice accelerated SAGE acquisition. Whole brain SAGE imaging is ideal in cases where spin- and gradient-echo perfusion parameters or blood-brain barrier leakage information is desired, such as in suspected stroke or other diffuse perfusion-related pathologies.

Conclusion: Using slice-acceleration with SAGE acquisitions increases the number of slices acquired per TR, allowing whole brain coverage with a temporal resolution of ~1.5s and 5mm thick slices, which opens the potential for whole brain SAGE PWI acquisitions in a clinical setting.

References: 1. Schmiedeskamp et al. MRM, 2012; 68:20-40. 2. Schmiedeskamp et al. JCBFM, 2013; 1-12. 3. Setsompop et al. NeuroImage 2012; 63:569-80. 4. Setsompop et al. MRM 2012; 67:1210-24. 5. Ugurbil et al. NeuroImage 2013; 80:80-104. 6. E Wong, ISMRM 2012, p. 2209. 7. Norris et al. MRM, 66:1234-1240, 2011. 8. Moeller, et al. MRM 2010; 63:1144-53. 9. Straka et al. JMRI 2010; 32(5):1024-1037.

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