Slice Accelerated Gradient-Echo Spin-Echo Dynamic Susceptibility Contrast Imaging with blipped CAIPI for Increased Slice Coverage

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Target Audience: MR Scientists and Clinicians with an interest in parallel MR acquisition

Purpose: Gadolinium (Gd) Contrast Agent (CA) based dynamic susceptibility contrast (DSC) MRI of combined gradient and spin echo (GESE) is an important and clinically approved method to quantify perfusion in healthy and tumorous brain tissue [1,2]. A high temporal sampling rate, which is necessary to sufficiently resolve the time course of the bolus passage, however limits slice coverage and resolution of this method. Simultaneous Multiple Slice (SMS) methods record more than one slice at a time and use parallel imaging to unfold these after the acquisition. Recent development in controlled aliasing methods for SMS MRI allows for a high Signal to Noise Ratio (SNR) retention of such acquisition[4,5]. The purpose of this study is to improve slice coverage of GESE sequences for DSC, without significant SNR penalty, using the blipped CAIPI SMS acquisition scheme [5].

Methods: Data were acquired on a 3T MR scanner (MAGNETOM Trio, Siemens Healthcare, Erlangen, Germany) with a 32-channel head coil (Siemens Healthcare Sector, Erlangen, Germany). A GESE EPI sequence was modified to employ blipped CAIPI SMS [5]. RF pulses were designed with a Shinnar-Le Roux (SLR) algorithm [6] and Variable Rate Selective Excitation (VERSE) to reduce energy transmission [7]. Dedicated software was developed perform real time online image reconstruction using the Split slice-GRAPPA algorithm with low contrast dependent leakage artifacts[8]. To evaluate SMS DSC, a two-fold slice accelerated (MB=2) GESE sequence with doubled slice-coverage was compared to a standard GESE sequence, both with 2x in-plane acceleration and identical time sampling rate. The protocol parameters for both standard and SMS acquisitions are TR=1500ms, TE(GE)=32ms, TE(SE)=98ms, 11/22 slices (no slice acc./MB=2), slice thickness = 5mm, 30% slice-gap distance factor, in-plane Field of View (FOV)=192mm×192mm, in-plane-resolution=1.5mm, in-plane acceleration of 2. The comparison was performed on two consecutive acquisitions (with and without slice acceleration) in one session, each with Gd injection, on three patients with glioblastoma. To enable evaluation of CA pre-dose effects on the second acquisition, one patient was scanned twice with reversed order of acquisitions. Perfusion analysis was performed for this data on healthy tissues as well as on tumor using NordicIce. For each subject, agreement between two measurements within healthy tissues was assessed by intra-class correlation coefficient (ICC) and repeatability coefficients (RC). Furthermore, SNR analysis was performed on one healthy subject with matching parameters to the patient scans but identical TR=3000ms and 22 slices for both type of acquisitions. Comparing the SNR values for both methods enables the calculation of retained SNR from GESE SMS MRI.

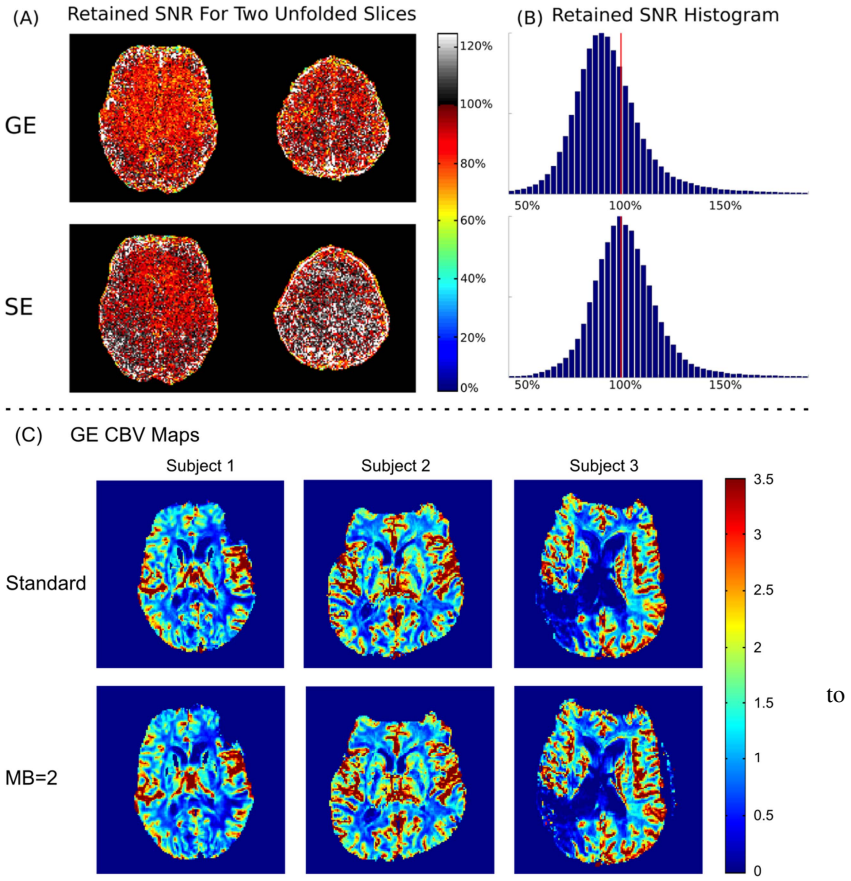

Fig 1 (A),(B):Results of the SNR comparison between an acquisition without slice acceleration and with an MB factor = 2. (C) Representative GE CBV maps generated from standard (first row) and SMS (second row) DSC for subjects 1, 2, and 3 (left to right).

Results: Retained SNR of MB=2 SMS DSC is 90% for a gradient echo (GE) and 99% for a spin echo (SE) acquisition, compared to a standard acquisition (Fig. 1 A,B). Comparing cerebral blood volume maps, it was observed that the results of standard and SMS acquisitions are comparable for both GE and SE images (Fig. 1 C). ICC and RC values are summarized in Table 1.

Discussion: This study shows that high quality DSC data can be acquired with an increased temporal efficiency using an SMS sequence. The additional slice acceleration was employed to record images with significantly larger slice coverage to achieve whole brain coverage, whilst preserving a sufficient time sampling rate. This study proposed a new DSC sequence to increase the brain coverage with a low SNR penalty. Comparison with data acquired in a former study shows, that RC and ICC of slice accelerated and non-slice accelerated acquisitions are similar to values that assess repeatability of only standard DSC data [9]. Thus, we conclude that SMS DSC can be employed with same confidence as standard DSC. Additionally to being able to analyze more brain regions, larger slice coverage improves the repeatability of specifying a reference tissue for normalization of the perfusion maps, which improves repeatability of measurements. This can help improve the confidence in tracking therapeutic responses of tumor patients. The results also point to a possibility to improve temporal sampling rate, while retaining the same slice coverage.

	GE		SE	
Scan #	ICC	RC	ICC	RC
1	0.97	0.25	0.78	0.25
2	0.95	0.32	0.65	0.28
3	0.96	0.34	0.79	0.33
4	0.95	0.39	0.56	0.54
Average	**0.96**	**0.33**	**0.70**	**0.35**

Tab 1 The values of ICCs and RCs reported for CBV within healthy regions.

References: [1]Weisskoff RM.Magn Reson Med 1994;31:601–610.[2]Boxerman JL.Magn Reson Med 1995;34:555–566.[3]Larkman DJ.J Magn Reson 2001;13:313–317.[4]Breuer FA.Magn Reson Med 2005;53: 684–691.[5]Setsompop K. Magn Reson Med. 2012;67:1210–1224.[6]Pauly J.IEEE Trans Med Imag 1991;10:53–65.[7]Conolly S. J Magn Reson 1988;78:440–458.[8]Cauley SF.MRM 2013:10.1002/mrm.24898.[9]Jafari-Khouzani KE.ISMRM 2013: 3061.