Clinical Implementation of Slice Accelerated EPI-DSC MR Perfusion Weighted Imaging

Donald Robinson Cantrell[1], Thomas Anthony Gallagher[1], Bruce Spottiswoode[2], Timothy Carroll[1,3], Charles Fasanati[1], and Dingxin Wang[4,5]
[1]*Department of Radiology, Northwestern University, Chicago, IL, United States,* [2]*Cardiovascular MR R&D, Siemens Healthcare, Chicago, IL, United States,*
[3]*Department of Biomedical Engineering, Northwestern University, Chicago, IL, United States,* [4]*Siemens Medical Solutions USA, Inc., Minneapolis, MN, United States,*
[5]*CMRR, University of Minnesota, Minneapolis, MN, United States*

Introduction: Magnetic Resonance Perfusion Weighted Imaging (MR-PWI) provides functional information on the hemodynamic status of central nervous system malignancies. Cerebral blood volume (CBV), which is derived from MR-PWI, has been correlated to tumor grade and to treatment response [1,2]. CBV can aid in the differentiation of primary CNS malignancies from solitary metastases and lymphoma [3], and it can help to distinguish tumor recurrence from radiation necrosis [4]. Dynamic-susceptibility contrast enhanced (DSC) MRI is a method that rapidly acquires MR images following gadolinium contrast injection to measure hemodynamic parameters including CBV, cerebral blood flow (CBF), mean transit time (MTT), and permeability. An optimal technique for DSC-MRI must balance spatial coverage, spatial resolution, temporal resolution, and SNR. Typical clinical EPI-based DCS-MRI protocols are performed with limited spatial coverage and a temporal resolution on the order of 1-2 seconds. Recently developed slice accelerated EPI can greatly reduce the volume acquisition time (TR). Slice acceleration techniques simultaneously excite multiple slices with multiband RF pulses and use parallel imaging to separate the aliased slices [5-7]. Our previous work demonstrated the feasibility of using slice accelerated EPI for DSC-MRI measurements in a controlled environment on healthy volunteers [8]. In the current study, we report the first large scale clinical implementation of this promising new protocol for the evaluation of CNS tumors

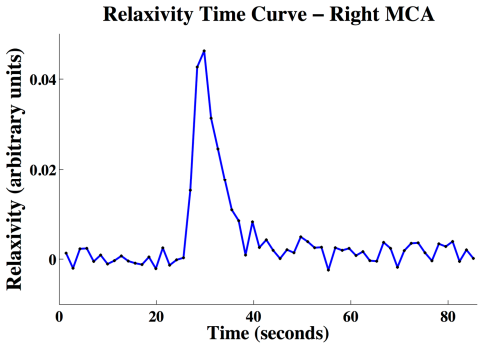

Fig1. The relaxivity time curve from the right MCA, an approximation for gadolinium concentration, demonstrates the improved sampling rate provided by parallel excitation.

Methods: A series of patients with WHO grade II, III or IV primary CNS tumors were evaluated with slice accelerated DSC MRI. MR Imaging was performed on a 3.0T Siemens clinical MRI scanner (MAGNETOM Skyra; Siemens AG, Erlangen, Germany) with a 20-channel head and neck receiver coil. The slice accelerated DSC-MRI protocol was performed using a gradient-echo EPI sequence with multiband RF excitation and simultaneous multi-slice acquisition. Imaging parameters included: TR/TE = 1420/39 ms, slice acceleration factor = 3, CAIPIRINHA FOV shift factor = 3 [7], excitation flip angle = 90º, slice thickness = 3 mm, 1565 Hz/pixel bandwidth, 220×220 mm^2 FOV, 128×128 matrix size, partial Fourier factor 6/8, 36 total imaging slices, slice spacing 20%. Dynamic images were acquired for 85 seconds following intravenous injection of 0.1mmol/kg body weight gadobutrol contrast agent (Gadavist, Bayer). Image reconstruction and DSC PWI data analysis was performed online at the console prior to exporting to PACS for clinical review. An SVD-based deconvolution method was used to compute tissue residue function [8]. The AIF was selected from the right middle cerebral artery. The rCBV was then calculated, and rCBV maps were fused to post-contrast T1 FLASH images.

Results: Slice accelerated DSC-MRI was successfully implemented in the clinical setting. The rapid volume acquisition time of the slice accelerated DSC-MRI sequence allowed perfusion weighted imaging data to be collected on 36 brain slices providing ample coverage from the cranio-cervical junction to the vertex. This compares to only 13 slices that are acquired with our standard MR-PWI protocol. Representative perfusion images acquired in a 68 year old female with a history of glioblastoma multiforme are shown in Figure 2. Following surgical resection of the primary mass, the patient underwent concomitant whole brain radiation and temozolomide chemotherapy, with 9 subsequent cycles of single-agent temozolomide. The patient presented to Northwestern Memorial Hospital with progressive mental status decline, which was felt to be out of proportion to changes in tumor burden. Initial MRI without perfusion demonstrated an irregularly enhancing mass with central necrosis in the left frontal lobe. Prior outside imaging was not available for review. MR perfusion imaging was recommended to aid in the differentiation of hyperperfused tumor from radiation necrosis. Despite patient motion and susceptibility artifact from prominent frontal sinuses, rCBV maps (Figure 2) demonstrated no evidence of elevated CBV within the enhancing component of the lesion, a finding that favored radiation necrosis over enhancing tumor, and suggested an alternative cause for the patient's mental status decline. The patient was diagnosed with a urinary tract infection, and her mental status improved following treatment.

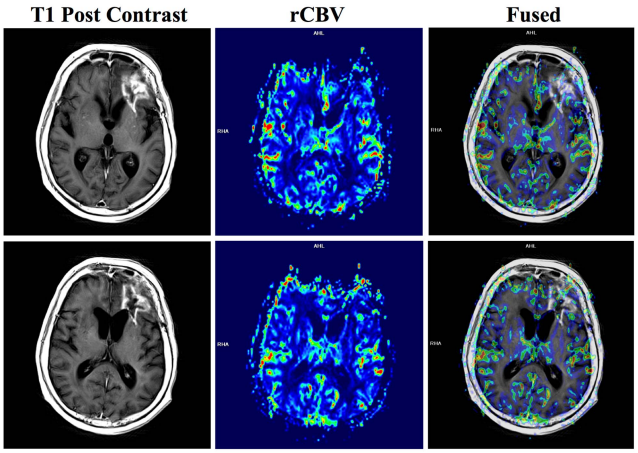

Fig 2. T1 post contrast, rCBV, and fused images through the level of the enhancing lesion with central necrosis in the left frontal lobe. There is no evidence of elevated rCBV in the enhancing component of the lesion.

Conclusion: Our study demonstrates, for the first time, the successful implementation of slice accelerated DSC-MRI perfusion weighted imaging in the clinical setting. Faster data acquisition allowed for increased spatial coverage while maintaining the temporal resolution required for derivation of functional hemodynamic parameters using an SVD-based deconvolution technique.

References: [1] Law, AJNR 2004, [2] Grossman, JMRI 2002, [3] Ma, AJNR 2010, [4] Hu, Neuro-oncology 2012, [5] Larkman, JMRI 2001, [6] Moeller, MRM 2010, [7] Setsompop, MRM 2012, [8] Wang, ISMRM 2013.