Dynamic Contrast Enhanced Whole Brain Perfusion using a Rapid 3D T_1-weighted Sequence at 1.5T and 3T

P. S. Morgan[1], M. S. George[2], F. A. Kozel[2], J. Fridriksson[3], G. C. Baylis[4], A. L. Martel[5], D. P. Auer[1], A. R. Moody[5]

[1]Academic Radiology, University of Nottingham, Nottingham, United Kingdom, [2]Center for Advanced Imaging Research, Medical University of South Carolina, Charleston, SC, United States, [3]Communication Sciences & Disorders, University of South Carolina, Columbia, SC, United States, [4]Psychology, University of South Carolina, Columbia, SC, United States, [5]Medical Imaging, Sunnybrook & Women's College Health Sciences Centre, Toronto, Ontario, Canada

Introduction: Various parameters of blood perfusion in the brain can be measured dynamically using MRI after administration of a bolus of paramagnetic contrast agent, such as cerebral blood volume (CBV) and cerebral blood flow (CBF). In order to quantify these parameters, a region representative of the AIF needs to be defined [1]. Passage of a bolus of contrast agent results in changes in the T_1 and T_2* of the surrounding region. In order to characterise these changes, a rapid MRI acquisition must be employed. EPI is a fast acquisition with inherent T_2* weighting and has been frequently used for perfusion studies. However, it requires a relatively high dose of contrast agent, limiting further contrast enhanced studies that may be required in the same clinical examination, such as angiography, and the susceptibility induced spatial distortion in EP images causes problems in acquiring regions low enough down in the neck to obtain a realistic AIF [2]. Rapid FLASH acquisitions have also been used to acquire dynamic images, preceded by a saturation or inversion pulse to create T_1 weighting [3]. FLASH suffers less from spatial distortion than EPI and so better AIF's may be obtained. The acquisition is slower and yields less spatial and temporal resolution than EPI. However, a lower dose of contrast agent is required, allowing a tighter bolus to be injected and the possibility of further contrast enhanced examinations. Previously, we developed and implemented a rapid 3D T_1 weighted FLASH technique on a 1.5 T MRI scanner [5]. Whole brain volumes are acquired every 2 seconds providing high temporal resolution. As with other 3D acquisitions, the signal to noise ratio (SNR) per 'slice' is increased compared to a similar 2D acquisition, slice cross-talk effects are eliminated and all slices are effectively acquired at the same time point.

We have extended this technique to a 3 T MRI system equipped with an eight element phased array head coil. The combination of a higher SNR and higher parallel imaging factors allow acquisition of thinner slices. This should result in higher spatial resolution of perfusion parameters and less contamination of the AIF by partial volume effects, allowing more precise quantification.

Method: The 3D FLASH sequence was implemented on both 1.5 T and 3 T Philips Intera systems. A non-selective inversion pulse transmitted on the body coil with a TI to null the signal from blood both in and outside the imaging volume, removing inflow effects. Two inversion-readout blocks were required to obtain one volume every 2.5 s (1.5 T) or 2.0 s (3 T). For each inversion pulse, 206 flow-compensated FLASH lines were acquired, using centre-out radial k-space ordering. Other parameters were TE=1.6 ms, time per FLASH line =2.7 ms, flip angle=15°. 30 consecutive volumes were acquired, with a short bolus of 3 ml of Gd-DTPA contrast agent hand-injected into the patient's antecubital vein at the fifth volume, followed by a saline flush. A suitable AIF was found in the internal carotid artery in an inferior slice and quantitative maps of perfusion parameters were calculated using the Peter's method [3] modified for use with MRI [4].
1.5 T: The k-space matrix size was 128x128x5, interpolated to 128x128x10 with interpolated voxel size 2x2x10 mm. The signal was received using two surface coils (synergy flex large) placed laterally to the head. A SENSE factor of 1.6 was used.
3 T: The k-space matrix size was 128x128x10 with actual voxel size 2x2x10 mm. An eight element SENSE head coil was used with SENSE factor 2.6.

Results: Comparative data were acquired successfully at 1.5 T and 3 T using healthy volunteers.

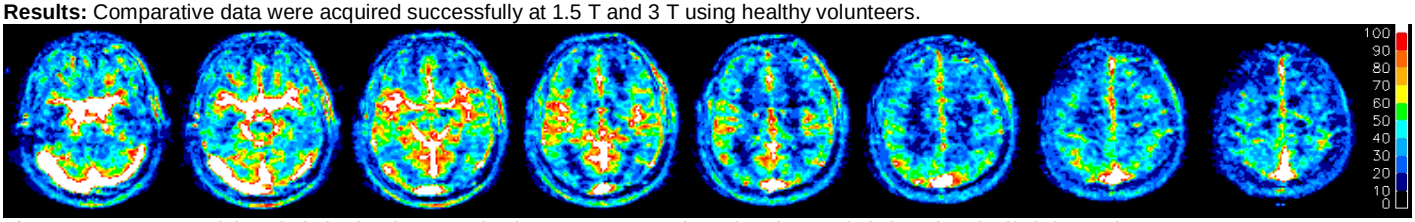

Figure 1. CBF maps of the whole brain of a normal volunteer at 1.5 T. The colour bar scale is in units of ml/min/100g tissue.

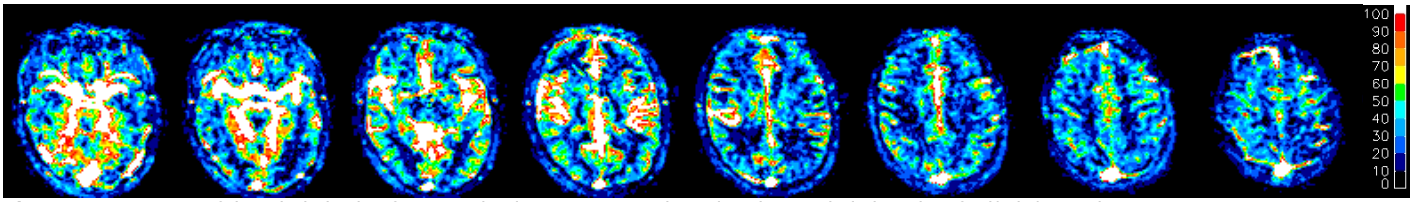

Figure 2. CBF maps of the whole brain of a normal volunteer at 3 T. The colour bar scale is in units of ml/min/100g tissue.

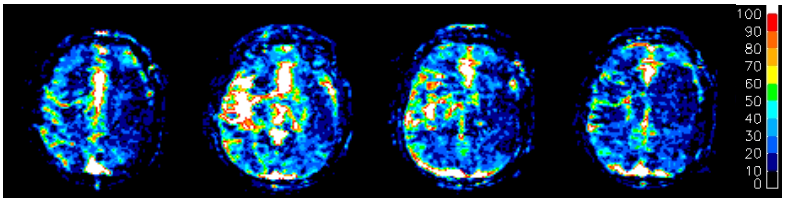

Figure 3 CBF maps from a patient with a large MCA infarct at 3 T

Discussion: High quality quantified perfusion maps through the brain can be produced using the new 3D T_1 weighted sequence at both 1.5 T and 3 T. Quantitative perfusion values are in good agreement with accepted values [1]. The extra SNR and higher SENSE factor at 3 T allow 10 true slices to be acquired, compared to 5 slices at 1.5 T interpolated to 10. The improved real resolution results in better definition of the AIF due to reduced partial volume effects, making the technique more robust. The thinner slices at 3 T also show a clearer distinction between perfusion values in white and gray matter. This technique shows promise for studying vascular diseases in the brain at 1.5 T and 3 T and has been applied to patients with stroke (see Figure 3), tumor and in drug studies.

References:
1. Calamante F. *et al*. *J Cerebr Blood F Met*. **19**:701-735 (1999)
2. Hacklander T *et al*. *J Comput Assit Tomo*. **21**:857-866 (1997)
3. Peters AM. *et al*. *Nucl Med Commun*. **21**:857-866 (1987)
4. Moody AR *et al*. *Invest Radiol*. **35**:401-411 (2000)
5. Morgan PS. *et al*. Proc ISMRM p.2196 (2003)