Optimising Image Readout for Perfusion Imaging at 7T

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INTRODUCTION: ASL is a powerful, non invasive method of monitoring tissue function but its performance is usually compromised by the poor image quality it provides. Ultra-high-field (UHF) provides increased signal to noise ratio (SNR) and lengthened longitudinal (T_1) relaxation times giving a theoretical increase in contrast to noise in ASL images [1] which can be used to improve the spatial resolution. ASL methods are often based on Echo Planar (EP) imaging readouts due to their rapid image acquisition time. However, EP images are prone to artifacts induced by the susceptibility and chemical shift effects, and at high spatial resolution single shot EPI images will have a lengthened echo time, and so suffer from reduced signal due to the shortened T2/T2* particularly at UHF. Non-EP methods such as Turbo-FLASH (TFL) [2] or TrueFISP [3], have been suggested as alternative acquisition techniques for combination with ASL, however their acquisition time per slice is increased. Here we assess the feasibility of these alternative fast field echo methods and compare ASL data collected at high resolution at ultra-high field (7T).

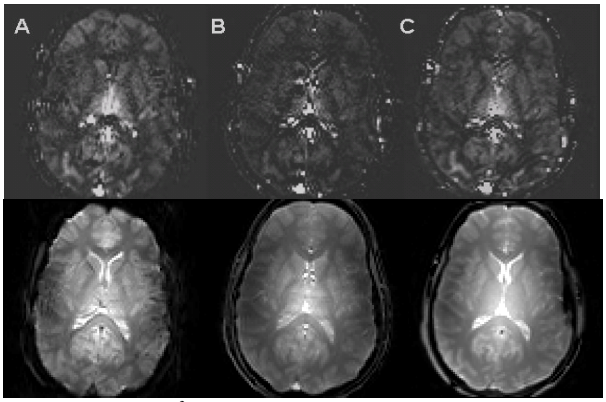

Figure 1: 2x2x3mm^3 ASL and base images in visual/temporal lobe with (A) GE-EPI (B) TFL and (C) TrueFISP acquisition.

METHOD: 6 healthy volunteers (5 females, 28±5 years) were scanned on a Philips Achieva 7.0 T scanner using a head-volume transmit coil and 16-ch SENSE receive coil. For all acquisition techniques an identical FAIR QUIPSSII tagging scheme was used (selective inversion 10mm wider than imaging volume/non-selective thickness 230mm) with an optimised FOCI inversion pulse to improve labelling efficiency and a post-label delay (TI) of 1500 ms. WET in-plane pre- and post-saturation pulses were applied to limit static signal contamination. Data was collected with 192 mm x 192 mm FOV, SENSE acceleration factor 2, half scan partial factor 0.75, with a TR of 6.2s per pair. Images were acquired with a 3 mm slice thickness and 1 mm or 2mm in-plane resolution. 90 tag/control pairs were acquired at 2 mm in-plane and 125 dynamics at 1 mm in-plane. 4 contiguous axial slices were acquired for the EPI and TFL images, however SAR restrictions at 7T limited the TrueFISP acquisition to a single slice. Imaging parameters were; GE-EPI: TE = 10ms at 2 mm in-plane which significantly lengthened to 24 ms at 1 mm in-plane, acquisition time per slice (acq) = 30 ms/ 73ms, background suppression was used to reduce physiological noise with two inversion pulses at 402ms and 639ms. TFL: TR/TE = 5.0/2.5ms, flip angle 15^o, centric ordering, bandwidth = 506Hz/pixel, acq = 165ms/ 315ms; TrueFISP: TR/TE = 3.6/1.8ms, flip angle 50^o, centric ordering, bandwidth = 866Hz/pixel acq = 120 ms/ 260ms. Following each ASL acquisition, a base M_0 image was acquired using a TR of 5s and inversion recovery (IR) images at 10 inversion times (TI: 100 to 2600 ms) to form T_1 and M_0 maps. The label and control scans were subtracted to obtain perfusion weighted (PW) data. The SNR for each acquisition method was then calculated from the mean PW signal in the grey matter divided by the variance in the white matter, grey and white matter being defined from segmentation of the IR using the FAST segmentation algorithm (FSL, FMRIB, Oxford). The coefficient of variation (CoV) of the signal was also measured as (standard deviation / mean) of the GM control signal.

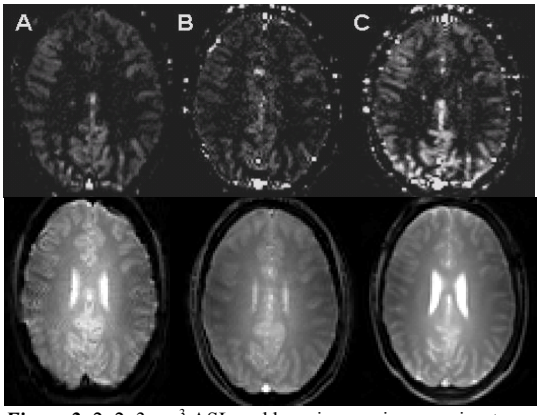

Figure 2: 2x2x3mm^3 ASL and base images in sensorimotor cortex with (A) GE-EPI, (B) TFL and (C) TrueFISP acquisition

RESULTS: Figure 1 shows representative 2 mm in-plane PW and base images for GE-EPI, TFL, and True FISP for an axial slice through the visual cortex and temporal lobe. Figure 2 shows slices through the sensorimotor cortex. The average SNR over the 6 subjects for EPI was 1.6±0.2, FLASH 1.4±0.2 and TrueFISP 2.3±0.1. The reduction in image distortions using TrueFISP is clearly visible, particularly on the lower slice, Fig. 1, where delineation of auditory and visual cortex is improved and a more uniform pattern of ASL signal is seen. The CoV was 0.065±0.07 for EPI, 0.023±0.003 for FLASH and 0.0221±0.002 for TrueFISP demonstrating less measurement variability of FLASH and TrueFISP compared to EPI. Figure 3 shows 1mm in-plane resolution EPI ASL data suffers from significant reduction in SNR and susceptibility effects at this increased spatial resolution, with TrueFISP having sufficient SNR for clear delineation of cortex at this resolution.

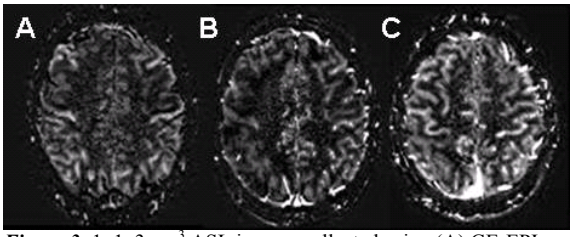

Figure 3: 1x1x3mm^3 ASL images collected using (A) GE-EPI (B) TFL and (C) TrueFISP acquisition.

DISCUSSION: We have shown the feasibility of Turbo-FLASH and TrueFISP for ASL image encoding at 7T. Non-EP based methods provide improved spatial resolution without significant SNR penalty or susceptibility artifacts, providing methods for comparison with structural malformations. TrueFISP provides the best SNR, however slice coverage is limited due to SAR at 7T. The use of anatomical imaging techniques in combination with ASL will benefit the study tumour patients where the ability to directly compare haemodynamic abnormalities with structural changes will be clinically valuable.

REFERENCES: [1]. Gardener, et al. MRM, 2009. 61:874-882. [2] Jahng et al. Med Phys. 2007 34(11): 4519–4525. [3]. Grossman et al., JMRI 29:1425-1431 (2009) **ACKNOWLEDGEMENTS:** This work was supported by the MRC.