Single-Shot Multi-Slice Perfusion Weighted Imaging Using EVISTAR

W. van der Zwaag[1], S. Francis[1], R. Bowtell[1]

[1]Sir Peter Mansfield Magnetic Resonance Centre, University of Nottingham, Nottingham, United Kingdom

Introduction

In multi-slice arterial spin labelling (ASL) experiments, images are acquired in rapid succession with slice acquisition ordered from distal to proximal to the tag. This is an inefficient way to monitor perfusion as in-flowing, tagged blood reaches the proximal slices first (1). However, if the slice acquisition order is reversed, tagged blood magnetisation destined for more distal slices is destroyed. Echo Volumar Imaging (EVI) (2), allows a multi-slice image to be acquired in a single shot. In this study, EVI is combined with Signal Targeting with Alternating Radio frequency (STAR) (3) to produce a three-dimensional perfusion imaging technique – EVISTAR. EVISTAR provides more uniform perfusion sensitivity across multiple slices, simplifies image processing and reduces sensitivity to through slice motion. EVISTAR was used with (DW) and without diffusion weighting (NDW) to quantify resting grey matter perfusion and arterial blood volume, respectively. EVISTAR has also been used in an fMRI experiment to examine simultaneous BOLD and perfusion changes on activation.

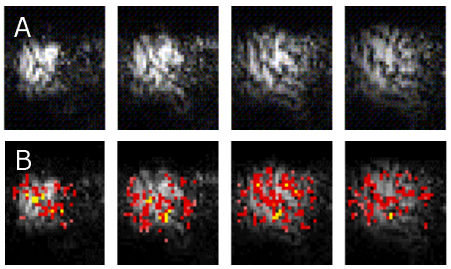

Figure 1.
A) Four slices from sagittal IR EVI image data
B) DW image, TI = 2200 ms overlaid on A.
Threshold = 0.7 % signal change.

Methods

All subjects were scanned using a 3 T scanner with a 27-cm diameter TEM volume excitation coil and a home-built, 4-cm diameter, receive surface coil. The EVI sequence was implemented with rewind gradients and reference maps were used to reduce image distortion (4). Data were acquired with 3 x 3 x 3 mm^3 resolution in a 64 x 32 x 8 matrix. This imaging slab was placed sagittally over the somatosensory/motor cortex. Immediately prior to tagging, magnetisation in the imaging slab was saturated. 50-mm wide tag/control slabs were also applied sagittally. One tag/control image pair was sampled every 6 s. 6 parameter AIR motion correction was applied on all data. Tag-control pairs were subtracted to form perfusion difference images.

Four subjects were scanned in NDW experiments. Thirty perfusion difference images were acquired at 6 TI values ranging from 600 to 1400 ms. Blood flow in areas with a signal change greater than 2 % was assumed to be dominated by the arterial blood component. Signal from these areas was fitted to a non-exchange arterial blood flow model (5). The study was repeated for 4 subjects with diffusion weighting (b = 1.5 mm^2s^{-1}), using TI values ranging from 1400 to 2800 ms. The DW results were fitted to a tissue perfusion model (5).

fMRI data were acquired with an echo time of 44 ms and a TI of 1.2 s. Subjects (n=4) were shown a visual cue for 60 seconds, during which they were asked to tap their fingers, followed by 60 seconds rest. This cycle was repeated 10 times, resulting in a total experimental time of 20 minutes.

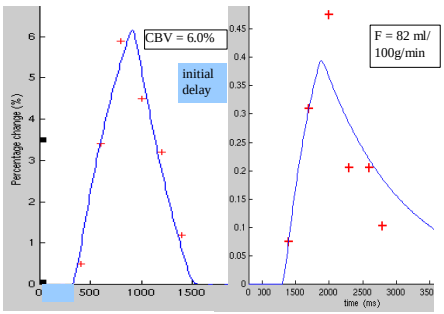

Figure 2A.
An example of a fit to arterial blood flow.

Figure 2B.
An example of a fit to resting tissue perfusion.

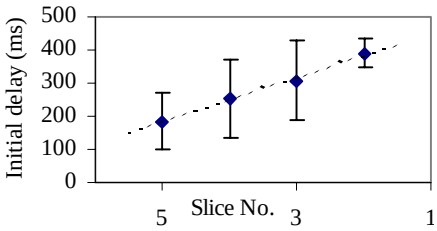

Figure 3. Initial delay versus slice number averaged across four NDW experiments. More distal slices have lower slice numbers.

Results and Discussion

An example of a DW perfusion difference image with a TI of 2200 ms, overlaid on a grey matter nulled inversion recovery (IR) EVI image is shown in Figure 1. As expected, high perfusion difference values correlate well with grey matter areas.

An example of a fit to NDW data is shown in figure 2A. For the four subjects, initial delays were found to range from 150 to 400 ms in NDW data and increased from proximal to distal slices (Figure 3). CBV values in the selected areas ranged from 2 to 8%. Addition of diffusion weighting attenuated the arterial signal component. DW-images acquired using long TI values yielded perfusion values of 84 and 86 ml/100g/min, in agreement with literature values (6).

The difference images from the fMRI study were used to identify blood flow changes correlated with the motor task. Control images were used to identify areas of BOLD activation. For all subjects, activation was found in the primary motor cortex in both BOLD and perfusion maps. An example of activation data overlaid on IR-EVI data is shown in Figure 4. Difference signal increased by 89 % during activation. The BOLD signal change was found to be 4.6 %. Thresholds were chosen so that the number of voxels designated active was comparable in both maps to allow the comparison of activation sites. Small differences in the site of activation identified by the BOLD and perfusion data may be due to the different physiological basis of the signal changes.

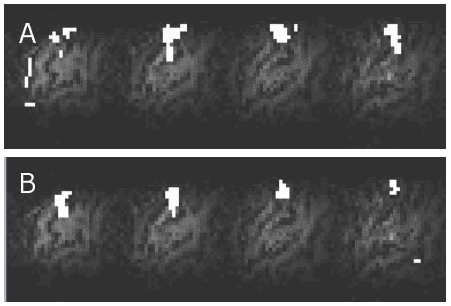

Figure 4. Activation maps based on:
A) BOLD contrast ($p_{corr} < 0.01$) and
B) Difference images ($p_{corr} = 0.05$).

Conclusions

EVISTAR has been shown to be advantageous for quantitative, multislice ASL perfusion fMRI. Future work will include quantifying grey matter perfusion changes on activation.

References: (1). Y. Kao, 1998, Magn Reson Med, 39:662-665. (2). P. Mansfield et al, 1995, J Comput Assist Tomogr. 19:847-52; (3). R.R. Edelman, 1994, Radiology, 192:513-520. (4). W. van der Zwaag, 2004, Proc. ISMRM 2004, p. 207. (5). C. Hoad, 2004, Proc.ISMRM 2004, p. 271. (6). E. Barbier et al, 2001, J Magn Reson Imaging 13:496-520.