

Double Acquisition Background Suppressed (DABS) FAIR at 3T and 7T: advantages for simultaneous BOLD and CBF acquisition.

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Introduction: There are significant potential advantages to acquiring ASL data at high magnetic field including increased signal-to-noise ratio (SNR) and longitudinal relaxation times leading to increased contrast-to-noise ratio (1,2). However, ultra-high field also presents several challenges such as increased B_1 and B_0 inhomogeneity, and physiological noise (2). Background suppression techniques (BS) (3), acquiring images at the null point (Fig.1), have been shown to reduce physiological noise. However, the low intrinsic signal of background suppressed images generally prevents this technique from being used in fMRI studies for the simultaneous acquisition of perfusion (CBF) and BOLD data. Here we implement a Double Acquisition Background Suppressed (DABS) method at 3 and 7 T to simultaneously measure CBF and BOLD changes in response to a finger tapping task.

DABS: Background suppression is achieved by applying an inversion recovery sequence to the ASL image volume. First, the optimal number of inversion pulses was evaluated; an increased number of pulses causes nulling across a greater range of TIs but can attenuate ASL signal due to the non-ideal performance of the inversion pulse, particularly at high field. The timing of the inversion pulses was optimised (Fig. 1) assumed T_1 values for white, grey, blood, CSF: 800, 1300, 1600, 3700 ms at 3 T and 1200, 1850, 2100, 4500 ms at 7 T respectively. For a label delay of 1550 ms, optimal timings were $TI1=507$, $TI2=688$ ms at 3T, and $TI1=402$, $TI2=639$ ms at 7T. In DABS, the second volume is acquired immediately prior to the end of the TR period of the first acquisition at an optimal TE for BOLD contrast, to provide data for the simultaneous assessment of BOLD, with CBF from the first acquisition (Fig. 1).

Methods: A DABS FAIR sequence (using spatially limited non-selective slab width for short TR acquisition) was implemented on 3 and 7T using two background suppression pulses as described above (volume/body transmit with SENSE receive RF coil at 3/7 T). In-plane saturation was provided by WET pre- and post-saturation pulses. Images were acquired using SENSE factor 2, at two spatial resolutions: 3 mm isotropic (Lo-Res) and 1.5 x 1.5 x 3 mm³ (Hi-Res) with a TE optimised to match T_2^* at 3 and 7T (N = 90). 5 contiguous slices were acquired per volume in ascending order with minimal temporal spacing. Respiration and cardiac pulsation were recorded. The functional paradigm was a bilateral finger tapping task: 12 s ON, 24 s OFF repeated for 15 cycles. Data was realigned using the second acquisition of DABS, and parameters applied to the first acquisition. The data were processed in SPM5 to identify activated areas ($p=0.005$; FWE correction applied only to BOLD). For validation, standard FAIR data (no BS) was also acquired with both CBF and BOLD maps created from the EPI readout.

Results: Figure 2 shows a comparison of BOLD (A) – (D) and perfusion weighted ((E)-(F)) images: (A,E) Lo-Res FAIR at 3T, (B,F) Lo-Res DABS at 3T, (C,G) Lo-Res DABS at 7T, and (D,H) Hi-Res DABS at 7T.

Although the size and t-score of the activated region in BOLD images at 3T is reduced by using DABS (192 to 43 voxels, maximum t-value 13.16 to 8.84, respectively) as a result of lower SNR, the sensitivity to perfusion weighted changes on activation is considerably increased (from 14 to 42 voxels, maximum t-value from 4.44 to 5.80; Fig.2 (E) compared to (F)). Since 7T offers more SNR and CNR and so activated areas are dramatically larger in comparison with 3T even with DABS for BOLD acquisition (from 42 voxels at 3T to 592 voxels at 7T and t-value from 5.80 to 10.29 for CBF (Fig. 2 (G) to (E)); from 43 to 534 voxels and t-value from 8.84 to 14.32 for BOLD (Fig. 2 (C) to (A)). Lo-Res activation areas at 7T (both CBF and BOLD) contain more voxels compared to Hi-Res due to partial voluming, but Hi-Res images have similar t-value (8.49 for CBF and 12.11 for BOLD) to Lo-Res (Fig. 2 (H) to (G)), but are better localised to the site of functional activation.

Conclusions: FAIR DABS provides a method for simultaneous acquisition of BOLD and CBF data; BS improves detection of CBF changes whilst the second acquisition maintains sensitivity to BOLD. The technique has been implemented at 3 and 7T, with sufficient SNR at 7T for high resolution studies; Future work will quantify the effects of BS on the physiological noise suppression at low and high spatial resolution.

References: [1] Franke et al, Magn Reson Imaging, 1109–1113, 2000. [2] Gardener et al., MRM, 2008 (in press), [3] Garcia et al., MRM, 54,336-372, 2005. Acknowledgements: This work was supported by the MRC and MCEST.

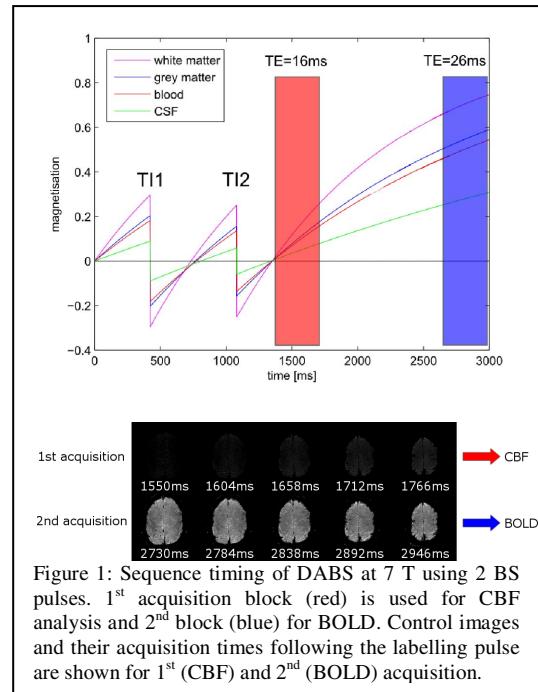


Figure 1: Sequence timing of DABS at 7 T using 2 BS pulses. 1st acquisition block (red) is used for CBF analysis and 2nd block (blue) for BOLD. Control images and their acquisition times following the labelling pulse are shown for 1st (CBF) and 2nd (BOLD) acquisition.

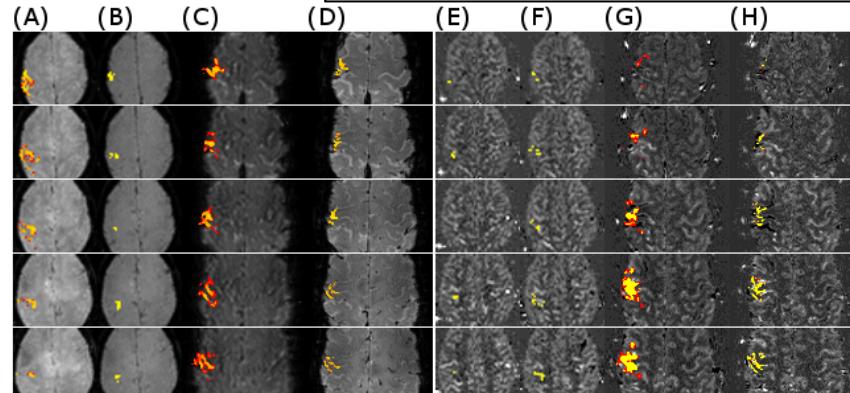


Figure 2: 3T BOLD images at 3 mm isotropic resolution for standard FAIR (A) and with DABS (B); 7T BOLD images using DABS at 3 mm isotropic resolution (C) and 1.5x1.5x3 mm³ (D). 3T perfusion weighted (PW) images at 3 mm isotropic resolution using standard FAIR (E) and with DABS (F); 7T PW images DABS 3 mm isotropic resolution (G) and 1.5x1.5x3 mm³ (H). All images have overlaid activated regions.