Vascular and Parenchymal Changes in Gradient Echo BOLD Signal during Global Flow Increase as a Function of Magnetic Field Strength

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INTRODUCTION

One of the main motivations for performing BOLD-based fMRI experiments at higher field strengths is the reduction of vascular response (relative to parenchymal) and improvement of image sensitivity. Although temporal SNR plateaus due to limitations caused by inherent physiological fluctuations in the fMRI data [1], increases in activation-induced BOLD signal change are known to occur at higher field strengths [2]. In this study we examine the effect of magnetic field strength on the fMRI BOLD response in areas of cortical gray matter and major veins. To achieve global increases in CBF in cortical gray matter, we used hypercapnia (CO2 inhalation), which is known to produce global increases in CBF. The resultant BOLD responses were estimated throughout cortical grey matter using gradient-echo EPI. Strong vascular BOLD responses were observed at both field strengths, but these peaked at shorter echo times than those at which the maximal parenchymal response was seen. To control for possibly different levels of hypercapnia during experiments on the different imaging systems used, we collected ASL-based flow measurements simultaneously with the BOLD observations and characterized the BOLD signal change per unit of CBF change, which should reflect the contrast characteristics at each field strength.

METHODS

- Comparative studies were performed at two different field strengths; a 1.5T (Sonata) and 3T (Trio) Siemens systems (Siemens, Erlangen, Germany). A commercial 8-channel phased array receive head coil was used.
- Images from 4 healthy volunteers were acquired at each scanner.
- Data acquisition and reconstruction achieved using GRAPPA (af=2) to facilitate multi-echo imaging.
- Block design paradigm, alternating 2min baseline condition - 2min breathing CO2 mixture.

- **IMAGING PROTOCOL**

➢ ***Pulsed ASL perfusion sequence*** [3]
TR=3000msec, FOV=192mmx192mm, matrix=64x64, 10 slices, slice thickness=3mm, 200 frames, $TE_{1.5T}$=40msec, TE_{3T}=30msec, PASL-TI1=700msec, PASL-TI2=1400msec.

➢ ***Multi Echo EPI sequence during global activation using CO2***
TR=3000msec, FOV=192mmx192mm, matrix=64x64,10 slices, slice thickness=3mm, 200 frames, 9 echo times; **$TE_{1.5T}$=11, 23, 35, 47, 59, 71, 83, 95, 107** and **TE_{3T}=8, 20, 35, 48, 61, 75, 88, 101, 115**.

- **DATA ANALYSIS**

➢ ***fMRI data analysis***
BOLD sensitivity was determined from the multi-echo data sets, by fitting a General Linear Model plus correlated noise, after removing motion and linear type trends at each echo [4]. Changes in BOLD signal and CBF were estimated in regions of cortical gray matter. BOLD signal change was also estimated in major veins.

BOLD contrast fluctuation across Echo Time and Field Strength

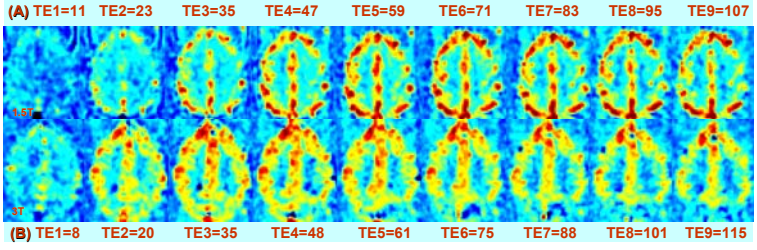

Figure 1: BOLD t-statistics maps across field strengths of 1.5T(A) & 3T(B) for various echo times (TE given in msec).

RESULTS

➢ Results in **Figures 1A** and **1B** demonstrate the dependence of the BOLD signal changes on echo time at 1.5T and 3T respectively. Note, prevalence of vessels at short TE, especially at 1.5T, while maximum BOLD change occurred at the respective T2* value of each tissue.

➢ **Figure 2** illustrates BOLD contrast as a function of echo time for gray matter and veins at both field strengths. The absolute signal decreases quasi-exponentially with TE. As expected T2* was shortened in veins relative to parenchymal.

➢ **Figure 3** shows the % change of BOLD at 1.5T and 3T, calibrated over the % of cerebral blood flow for the same ROIs of gray matter.

REFERENCES:
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BOLD Contrast across Field Strength and Echo Time

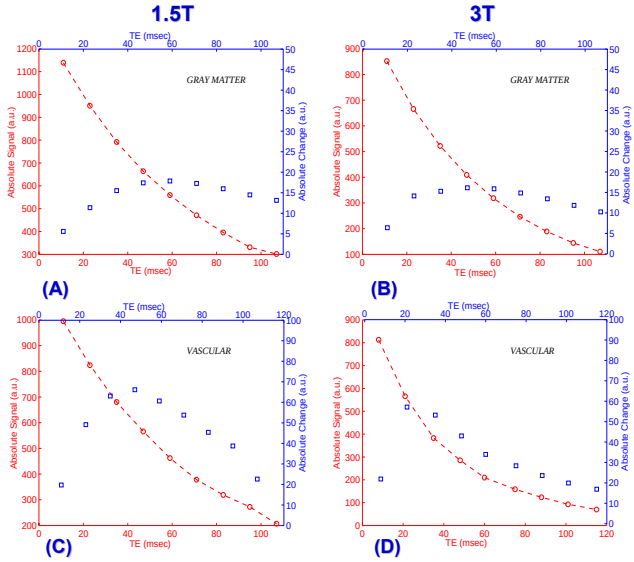

Figure 2: Absolute signal and absolute change of the signal averaged over 4 subjects for ROI's of gray matter (A), (B) and veins (C), (D) across field strengths of 1.5 T (A), (C) and 3 T (B), (D).

Δ% BOLD/ Δ% CBF Change across Field Strengths

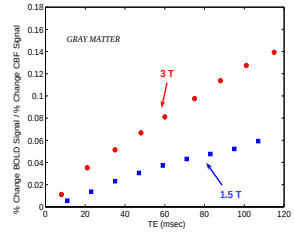

Figure 3: %Activation induced BOLD signal change across echo times normalized to Δ%CBF, for both 1.5 T and 3T

CONCLUSION

In this work we examined venous and parenchymal BOLD responses to a global challenge (hypercapnia) at field strengths of 1.5T and 3T. Peak vascular responses occurred at echo times shorter than the parenchymal. Functional experiments could therefore be carried out using GE TE values to avoid emphasis of the venous response components.