Moving Fluid Suppressed BOLD Signals Using DANTE Prepared Multislice EPI

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Background: When the blood oxygenation level dependent (BOLD) effect is detected using conventional GE-EPI, intravascular BOLD contributions can give rise to uncertainty in the localization and quantification of neural activity [1]. We have previously demonstrated [2] that during application of DANTE pulse trains (a rapid series of low flip angle RF pulses interspersed with gradients), the longitudinal magnetization of flowing spins is largely (or fully) attenuated due to phase dispersion accrued while flowing along the applied gradient. This is in contrast to static tissue, whose longitudinal magnetization is mostly preserved. Here, we propose the employment of DANTE prepared multislice EPI (DANTE-EPI) for whole brain BOLD signal measurement (Fig. 1). Based on the flow suppression feature of DANTE, we hypothesize that the intravascular BOLD signal will be largely suppressed and thus the venous blood contamination reduced. As such, the BOLD signal from DANTE-EPI may be more accurately located to the site of neuronal activity.

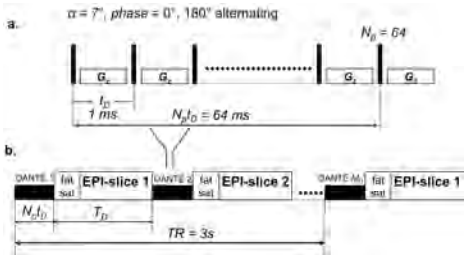

Fig 1. DANTE multislice interleaved acquisition

Methods:

1. Phantom Experiments: A flow phantom was scanned at a Siemens Verio 3T (32-channel head coil, GRAPPA=2, EPI readout, matrix/TR/TH/gap/FOV = 96x96, 3.19s, 4mm, 0, 22cm). The flow phantom consists of a tube of 5mm diameter fixated next to a water bottle. Flow rate was alternated between 1cm/s and 2cm/s at a period of 30s. The experiment duration was 120s. Two sequences were used: (1) DANTE-EPI with 128 7°-hard pulses, (2) GE_EPI with TE=35ms and flip angle of 90°. ROI comprised of pixels within the tube were selected for analysis.

2. In Vivo Human Experiments: Block-design finger-tapping experiments were carried out using the same scanning parameters as in the phantom experiments. Each cycle of the task consists of 30s off-period during which the subject's attention is kept at a fixation cross and 30s on-period of finger-tapping at 2Hz cued by visual display. 5 cycles were repeated and 100 time-frames were gathered. 3 subjects were participated and a total of 7 scanning sessions were carried out on different dates after giving informed consent. Each scan session consisted of 3 fMRI exams using (1) DANTE-EPI, (2) GE-EPI with flip angle of 70° to achieve similar SNR as in DANTE-EPI, and (3) spin-echo EPI (SE-EPI) with TE=80ms . A high-resolution T_1 image was gathered for registration and for display.fMRI data was analyzed using FSL.

Results: *1. Phantom Experiments*: Fig. 2 shows the time series from pulsed-flow phantom experiments, designed to assess the ability of DANTE-EPI to suppress flowing spin signal. It is evident that conventional EPI is sensitive to flow velocity changes (upper trace). In comparison, the DANTE-EPI time series signal from the flowing tube is suppressed and temporally insensitive to pulsatility (lower trace). The velocity used in this experiment (1-2cm/s) is similar to that found in smaller brain vessels, leading us to believe that the DANTE-EPI sequence may offer a method to suppress intravascular signal and vascular pulsatility artifact from BOLD fMRI data.

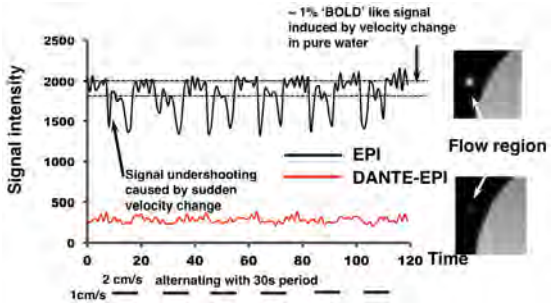

Fig. 2 Time series of flow phantom using EPI and DANTE-EPI. Flow velocity alternates between 1 and 2cm/s

2. In Vivo Human Experiments: Fig. 3 shows fMRI activation results from a volunteer collected using conventional GE-EPI, DANTE-EPI and SE-EPI. Activation from the three sequences is overlaid on high resolution T_1 structural data. Unlike SE-EPI, GE-EPI is more sensitive to T_2^* changes around veins and large vessels. Activation detected by GE-EPI (red) is likely to extend beyond the actual neuronal activation locations. SE-EPI activation (green) is more localized to capillary areas, so its activation volume is the smallest among the three sequences. Since DANTE-EPI (blue) reduces the contribution from draining veins, it helps to improve the specificity of activation areas. Fig. 4 shows four successive axial slices. The arrow indicates the location of a bridge vein, where intravascular BOLD effects contribute to "activation" detected with GE-EPI but its contamination is much reduced with the DANTE-EPI sequence (no blue).

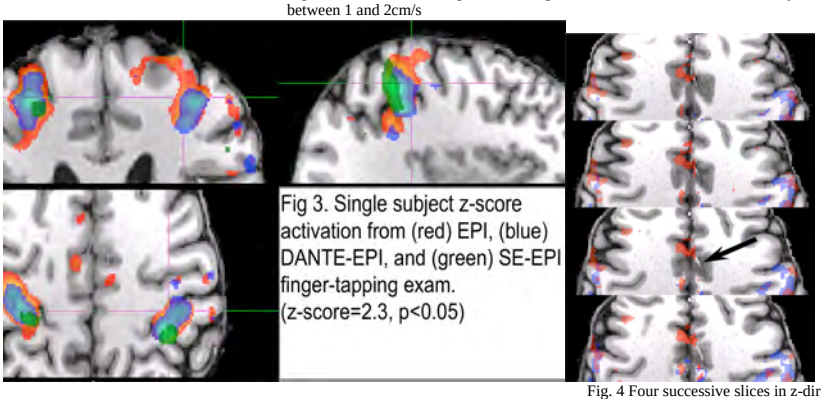

Fig. 4 Four successive slices in z-dirction

Discussion: Neuronal activation is believed to take place around capillaries, for which the blood flow velocity is on the order of 1mm/s. The DANTE preparation module, which typically uses flip angle of between 3° and 15°, will diminish signal from flowing spins above this value. Thus, the BOLD signal contribution from small and large vessels is reduced when the DANTE module is used. Experiments using a flow phantom show GE-EPI time series fluctuations that are effectively removed with DANTE-EPI. The results from the fMRI experiments support the idea that the DANTE-EPI sequence reduces the intravascular contribution in the BOLD signal, but likely restricts this effect, as desired, to the larger vessels. As shown in Fig. 3, the activation volume from DANTE-EPI is less than that from GE-EPI, while activation locations from DANTE-EPI in general overlap with those of SE-EPI. This suggests that DANTE is better localized to detect neuronal activity, as in SE. Note, however, that extravascular BOLD effects with DANTE-EPI will remain if a GE readout is used. Note also that DANTE-EPI for fMRI is most valuable when there is a need to suppress flowing spin signal from vessels with a velocity of >1cm/s.

Conclusions In this study, a novel DANTE-EPI technique for intravascular blood suppression was implemented. By incorporating the DANTE preparation module before a conventional gradient-echo EPI readout we observe a reduced signal contribution from flowing spins. DANTE-EPI may be a useful tool to achieve intravascular blood suppressed BOLD signal for better localization and quantification of neural activity.

Acknowledgements and References We thank the NIHR Oxford Biomedical Research Centre for grant funding. [1] Turner R (2002) NeuroImage. 16:1062–7. [2] Li L, Miller K and Jezzard P (2011) MRM, in revision.