SIMULTANEOUS MULTI-SLICE FUNCTIONAL CBV MEASUREMENTS AT 7 T

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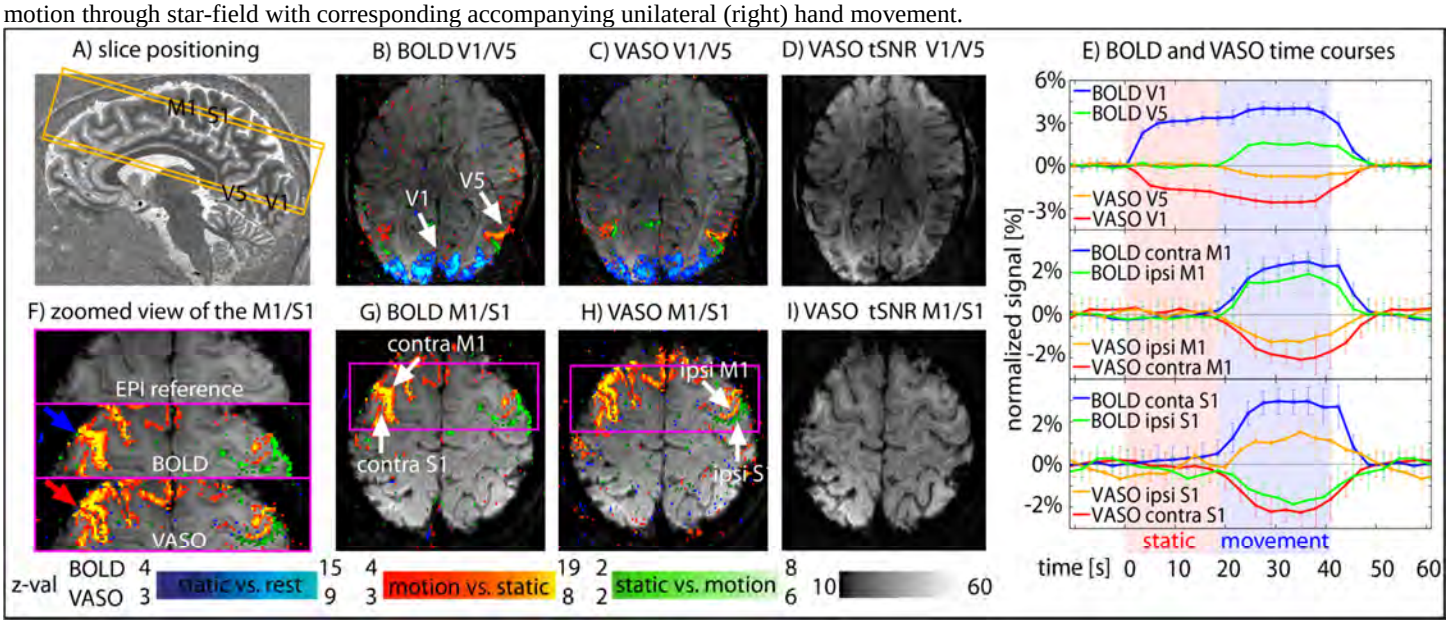
Purpose: Vascular space occupancy (VASO) MRI [1] measures functional changes of cerebral blood volume (CBV) without the need of an exogenous contrast agent. It has been shown [2] that it can map changes of brain activity with better spatial localization than GE-BOLD, and without contamination by remote draining veins. VASO is particularly attractive at high fields (7 T) due to the increasing image signal-to-noise ratio and the longer blood T_1 relaxation time, which approaches the vasculature refill time [3]. However, VASO requires a blood-nulling inversion pulse. Thus if multiple consecutive slices are acquired after each inversion, they end up with different inversion times (*TI*) limiting the brain coverage of this method. This is especially problematic at high resolution, which needs long acquisition trains. Using simultaneous multi-slice echo planar imaging (SMS-EPI) [4], however, multiple slices can be acquired at the same *TI*, enabling a larger number of brain areas to be covered. The purpose of this study is to implement and evaluate high-resolution VASO with simultaneous multi-slice EPI for concurrent functional imaging of VASO and BOLD signal in the brain areas V1, V5, M1, and S1 during a visuo-motor task. By this means we seek to overcome the former limitation of EPI-VASO to acquire only brain regions within one single slice.

Methods: Experiments were performed on a 7 T Siemens scanner with a 32-channel NOVA Medical head coil. Four volunteers participated in ten SMS-VASO experiments after giving informed consent. CBV and GE-BOLD weighted data were acquired simultaneously with SS-SI VASO [3] and *TI1/TI2/TR* = 1.0/2.5/3.0 s. To avoid inflow of fresh (not-inverted) blood, an optimized partial inversion adiabatic RF pulse was employed [3]. The readout strategy combined simultaneous multi-slice excitation with a 2D blipped-CAIPI 2 [5] and a ½ FOV-shift as well as in-plane GRAPPA-2 with FLEET [6]. Signals of simultaneous acquired slices are unaliased with the Split slice-GRAPPA optimization strategy [7]. The nominal voxel size was 1 × 1 × 1.5 mm^3, and the following parameters were used: partial Fourier (PF) 6/8, *TE* = 24 ms. The acquisition slices were positioned to include the brain areas V1, V5, M1, and S1 (Fig. A). The 12-min stimulation paradigm consisted of three repeating conditions, a) rest: fixation point and no hand motion, b) static visual star-field without motion, and c) visual motion through star-field with corresponding accompanying unilateral (right) hand movement.



Results: The tSNR of VASO and the BOLD signal in the areas of interest were 47 and 52, respectively (Fig. D/I). The statistical activation maps depict movement-dependent activation in V5 (visual), in contralateral (contra) M1/S1, and in ipsilateral (ipsi) M1/S1 (Fig. B/C and G/H). Differences in activation between static stimulation and rest are confined to V1 (blue in Fig. B/C). In the sensory-motor cortex (M1/S1), BOLD activation maps do not discriminate activations on the opposing banks of the central sulcus (blue arrow in Fig. F). Activation maps in VASO, on the other hand, distinguish clearly between M1 and S1 (red arrow in Fig. F). Ipsilateral S1 shows a significant negative response to motion, while ipsilateral M1 shows a positive response, a feature only resolvable at high spatial resolution. Fig. E shows averaged BOLD and VASO signal time courses in multiple simultaneously acquired visual and motor systems.

Discussion: These data demonstrate that SMS-VASO can provide sufficient SNR to simultaneously acquire multiple brain areas with high resolution. The fact that VASO maps distinguish activity on each bank of the central sulcus (M1/S1) is consistent with the interpretation that CBV has better spatial localization without contamination by large draining veins, compared with GE-BOLD. This discrimination may also be assisted by the inherently different noise characteristics of CSF and GM in VASO and BOLD signals.

Conclusion: We have presented an SMS-VASO approach that simultaneously obtains CBV and BOLD signal changes at 7 Tesla in multiple brain regions of V1, V2, M1, and S1 at high spatial resolution. We have shown that SMS-VASO can cover multiple brain regions and provide significantly improved spatial specificity, distinguishing between activations in M1 and S1 across the central sulcus. This method may prove important in quantitative, non-invasive, ultra-high resolution investigation of multiple cortical regions and their interactions.

References: [1] Lu et al., MRM, 50:263-274; **[2]** Kim et al., NMR Biomed, 2013, 26: 949-962; **[3]** Huber et al., MRM, 2014, 72:137-148; **[4]** Moeller et al., MRM, 2009, 67:1144-1153; **[5]** Setsompop et al., MRM, 2012, 67:1210-1224; **[6]** Polimeni et al., ISMRM, 2012, p 2646; **[7]** Cauley et al., MRM, 2013, 72:93-102. M Guidi is funded by EU through Marie Curie HiMR ITN (PITN-GA-2012-316716).