Functional Mapping of the Human Visual Cortex with Intravoxel Incoherent Motion (IVIM) MRI

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Purpose

Focal brain neural activity increases local perfusion through neurovascular coupling [1], on which vascular-based brain imaging techniques are based, currently the most popular being the BOLD technique [2]. This method is robust but faces challenges due to the signal dependence on several parameters (cerebral blood flow, cerebral blood volume, and blood oxygenation) [3], while the spatial resolution is limited due to contribution from veins draining the sites of activation [4]. Intravoxel Incoherent Motion MRI is a method that allows measurement of microvascular blood flow [5, 6], and has recently been shown to produce high-resolution quantitative perfusion maps [7]. Therefore, functional imaging with IVIM could potentially have a higher spatial correlation with neuronal activation in comparison to BOLD.

Materials and Methods

Imaging was performed on 8 healthy subjects, using a standard EPI spin echo sequence with embedded Stejskal-Tanner pulsed gradients sequence, at 3 Tesla using a 32-channel receiver head-coil. An adiabatic inversion pulse was added to suppress cerebrospinal fluid, with a TI of 2660 ms. A single axial brain slice of 7 mm thickness was acquired on the calcarine fissure. Other image parameters were TR/TE 12s/92ms, in plane resolution 1.2x1.2mm, BW 1134 Hz/pixel and b-values of (0, 10, 20, 40, 80, 110, 140, 170, 200, 300, 400, 500, 600, 700, 800, 900 s/mm^2), in 3 orthogonal directions. Parametric maps were obtained by fitting the IVIM bi-exponential model [5], which permitted the extraction of the IVIM perfusion parameters, which are the perfusion-fraction f, the pseudo-diffusion coefficient D*, and the blood flow related parameter fD*. Quantitative analysis was performed by placing on the t-map of the BOLD experiment a region of interest in the visual brain, and another over the remaining brain in the slice excluding the occipital region. These regions of interest were further sub-segmented into white (WM) and gray matter (GM) using a corresponding high resolution T1 weighted image.

Results

An increase in flow could be observed in the visual cortex on single measurement parametric flow maps fD* during stimulation (fig. 1). Quantitative analysis demonstrated a statistically significant increase of all 3 IVIM perfusion parameters f, D*, and fD* during visual simulation in the visual cortex (50%, 77%, and 170% respectively). A less marked effect was also observed in the visual subcortical white matter (12%, 40%, and 70% respectively), which was statistically significant for the last two parameters. Finally, a trend of a slight decrease of around 20% was observed in the rest of the brain excluding the occipital region.

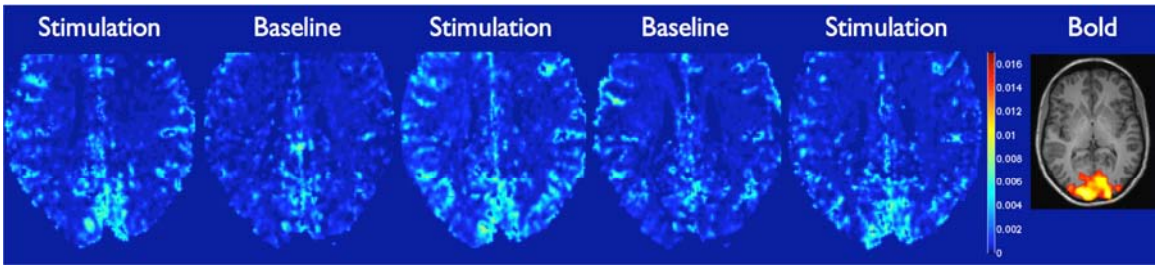

Fig 1: In plane high-resolution (1.2x1.2 mm) maps of the blood flow related IVIM parameter fD*, in 5 consecutive measurements in a single volunteer, showing an increase in visual cortex perfusion during stimulation compared to baseline. For comparison, the corresponding BOLD statistical t-map.

Discussion

Functional imaging with IVIM MRI in the visual cortex, as well as in the underlying white matter, is demonstrated. This is of particular interest, because the method has been shown to be quantitative [7] and of microvascular origin [5], which suggests a possible higher correlation with neural activation than BOLD fMRI. The observed effect in the subcortical white matter is noteworthy, while studies reporting evidence of BOLD signal measurement in WM regions are getting more numerous [9, 10], it remains controversial [8], Finally, the interesting observed trend to a slight decrease in the non-visual brain during visual stimulation may be related to a reduction in the activity of brain baseline default mode during specific tasks [11].

References

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