Blood oxygen level dependent functional magnetic resonance imaging

Functional MRI (fMRI): consists of 2 types (Task-based functional magnetic resonance imaging and resting state fMRI) and is based on the blood oxygen level-dependent (BOLD) effect, in which specialized MRI sequences measure/ detect regions of increased oxygen-rich blood flow to areas of upregulated neuronal activity. Both task-based and resting-state fMRI modalities have shown group differences between mTBI and control patients (specifically in frontal lobe dysfunction) but further studies need to be completed on both a single time point and longitudinal basis before these techniques can be widely adopted for individual diagnosis and therapeutic guidance [1].

Susceptibility weighted imaging (SWI), originally called BOLD venographic imaging, uses a type of contrast in magnetic resonance imaging (MRI) different from traditional spin density, T1, or T2 imaging.

Blood oxygen level-dependent (BOLD) functional magnetic resonance imaging (fMRI) is the most widely used technique to study brain function in the human brain.

The vast majority of human fMRI studies measure Blood-Oxygen-Level-Dependent (BOLD) contrast, which reflects regional changes in cerebral blood flow (CBF), cerebral blood volume (CBV) and blood oxygenation; all three vascular responses reflect local increases in neural activity [2].

Blood oxygen level-dependent fMRI relies on the coupling between increases in neuronal activity and increases in blood flow and volume that accompany the local increase in oxygen demand. With electrophysiological methods, changes in neuronal activity can be localized to the submillimeter scale of columnar or laminar structures, depending on the brain function studied

BOLD fMRI does not measure neuronal activity, but only a correlate thereof, since it measures blood dynamics. To confirm that BOLD activation maps reflect neuronal population activity patterns, a direct comparison with neuro-electrophysiological data from the same cortical patch is necessary.

The dilatory response is distributed throughout the vascular network. Arteries actively dilate within a second following neural activity increases, while venous distensions are passive and have a time course that last tens of seconds. Vasodilation, and thus local blood flow, is controlled by the activity of both neurons and astrocytes via multiple different pathways. The relationship between sensory-driven neural activity and the vascular dynamics in sensory areas are well-captured with a linear convolution model. However, depending on the behavioral state or brain region, the coupling between neural activity and hemodynamic signals can be weak or even inverted [3].

Blood-oxygen-level-dependent (BOLD) functional MRI (fMRI) has been routinely adopted for presurgical mapping of the surrounding functional areas. For completely utilizing such imaging data, here we show the feasibility of using presurgical fMRI for tumor delineation. In particular, we introduce a novel method dedicated to tumor detection based on independent component analysis (ICA) of resting-state fMRI (rs-fMRI) with automatic tumor component identification. Multi-center rs-fMRI data of 32 glioma patients from three centers, plus the additional proof-of-concept data of 28 patients from the fourth center with non-brain musculoskeletal tumors, are fed into individual ICA with different total number of components (TNCs). The best-fitted tumor-related components derived from the

optimized TNCs setting are automatically determined based on a new template-matching algorithm. The success rates are 100%, 100% and 93.75% for glioma tissue detection for the three centers, respectively, and 85.19% for musculoskeletal tumor detection. We propose that the high success rate could come from the previously overlooked ability of BOLD rs-fMRI in characterizing the abnormal vascularization, vasomotion and perfusion caused by tumors. The findings suggest an additional usage of the rs-fMRI for comprehensive presurgical assessment [4].

Siero et al., compare BOLD activation patterns obtained with fMRI at 7T to electrophysiological patterns obtained with implanted high density electrocorticography (ECoG) grids in the same patch of human sensorimotor cortex, and with similar resolution (1.5mm).

BOLD signal at 7T is strongly correlated with the underlying electrophysiology, and is capable of discriminating patterns of neuronal population activity at a millimeter scale. The results further indicate the utility of 7T fMRI for investigation of intra-area organization of function and network dynamics [5].

BOLD variability

BOLD variability

References

1)
Yuh EL, Hawryluk GW, Manley GT. Imaging concussion: a review. Neurosurgery. 2014; 75 Suppl 4: S50–S63
2)
Logothetis N. K., Wandell B. A. (2004). Interpreting the BOLD signal. Annu. Rev. Physiol. 66, 735–76910.1146/annurev.physiol.66.082602.092845
3)
Drew PJ. Vascular and neural basis of the BOLD signal. Curr Opin Neurobiol. 2019 Jul 20;58:61-69. doi: 10.1016/j.conb.2019.06.004. [Epub ahead of print] Review. PubMed PMID: 31336326.
4)
Huang H, Lu J, Wu J, Ding Z, Chen S, Duan L, Cui J, Chen F, Kang D, Qi L, Qiu W, Lee SW, Qiu S, Shen D, Zang YF, Zhang H. Tumor Tissue Detection using Blood-Oxygen-Level-Dependent Functional MRI based on Independent Component Analysis. Sci Rep. 2018 Jan 19;8(1):1223. doi: 10.1038/s41598-017-18453-0. PubMed PMID: 29352123.
5)
Siero JC, Hermes D, Hoogduin H, Luijten PR, Ramsey NF, Petridou N. BOLD matches neuronal activity at the mm scale: A combined 7T fMRI and ECoG study in human sensorimotor cortex. Neuroimage. 2014 Jul 12. pii: S1053-8119(14)00574-6. doi: 10.1016/j.neuroimage.2014.07.002. [Epub ahead of print] PubMed PMID: 25026157.