Resting-state functional magnetic resonance imaging

Resting state fMRI (rsfMRI or R-fMRI) is a method of functional magnetic resonance imaging (fMRI) that is used in brain mapping to evaluate regional interactions that occur in a resting or task-negative state, when an explicit task is not being performed.

A number of resting-state conditions are identified in the brain, one of which is the default mode network.

Functional magnetic resonance imaging (fMRI) based on blood-oxygen-level dependent (BOLD) techniques has been widely used to study the functional activities and cognitive behaviors of the brain based on the induced stimulus by tasks.

As task-based fMRI is widely adopted to identify brain regions that are functionally involved in a specific task performance, while resting state fMRI is used to explore the intrinsically functionally segregation or specialization of brain regions/networks, such differences could inspire better understanding for the organization and origination of the brain cognitive functioning. Also, determining whether participants are focusing on task during task scan or being rest during resting state scan could be very crucial for the further analysis.

Indications

Sparse dictionary learning is used to estimate a dictionary of resting state networks by decomposing the whole brain signals into several temporal features (atoms), each being shared by a set of voxels associated to a network.

This resting brain activity is observed through changes in cerebral blood flow which creates what is referred to as a Blood Oxygenation Level-Dependent Signal (BOLD) that can be measured using functional Magnetic Resonance Imaging (fMRI). Because brain activity is present even in the absence of an externally prompted task, any brain region will have spontaneous fluctuations in BOLD signal. The resting state approach is useful to explore the brain’s functional organization and to examine if it is altered in neurological or psychiatric diseases. Resting-state functional connectivity research has revealed a number of networks which are consistently found in healthy subjects, different stages of consciousness and across species, and represent specific patterns of synchronous activity.

Resting-state functional magnetic resonance imaging (fMRI) has been used to detect the alterations of spontaneous neuronal activity in various neurological and neuropsychiatric diseases.

Presurgical mapping

Resting-state functional magnetic resonance imaging (R-fMRI) is a promising tool in clinical application, especially in pre surgical mapping for neurosurgery, and a promising substitute for blood oxygenation level dependent functional Magnetic Resonance Imaging (T-fMRI) for presurgical mapping [1)].

Spatial localization of sensorimotor cortex using resting state correlation mapping compared well with localization using “gold standard” intraoperative cortical stimulation mapping. Resting state correlation proved to be a reliable method that produced consistent maps over multiple scans.

This method may be less variable than maps obtained with a standard task-based fMRI protocol. Resting state analysis revealed specificity of correlations within the sensorimotor network even when task-based fMRI showed multiple cortical systems correlated with the task. Finally, functional localization can be achieved even when the task-based method fails or when the patient is unable to perform the task. These findings demonstrate the utility of resting state correlation mapping as a potential tool for preoperative functional localization though this limited case series needs to be expanded before definitive conclusions can be drawn [2)].

This approach uses the endogenous brain activity detectable with BOLD MRI to identify areas that are interacting at rest. Spontaneous BOLD fluctuations are low-frequency (<0.1 Hz) oscillations in metabolic activity that are anatomically correlated within distinct functional networks [3)].

First reported by Biswal et al, [4)] there is strong coherence which is reproducibly present between the left and right somatomotor cortices [5)], between language areas, [6) 7)]

Recent research in brain imaging has highlighted the role of different neural networks in the resting state (ie. no task), where the brain displays spontaneous low frequency neuronal oscillations. These can be indirectly measured with resting state functional magnetic resonance imaging (rs-fMRI), and functional connectivity can be inferred as the spatio-temporal correlations of this signal. This technique has proliferated in recent years, and has allowed for the non-invasive investigation of large-scale, distributed functional networks.

The use of rs-fMRI in neurosurgical contexts, specifically with respect to neurooncology, epilepsy surgery, and deep brain stimulation [8)].

Hemifacial Spasm

Tu et al. used resting-state fMRI with regional homogeneity (ReHo) analysis to investigate changes in spontaneous brain activity of patients with hemifacial spasm HFS and to determine the relationship of these functional changes with clinical features. Thirty patients with HFS and 33 age-, sex-, and education-matched healthy controls were included in this study. Compared with controls, HFS patients had significantly decreased ReHo values in left middle frontal gyrus (MFG), left medial cingulate cortex (MCC), left lingual gyrus, right superior temporal gyrus (STG) and right precuneus; and increased ReHo values in left precentral gyrus, anterior cingulate cortex (ACC), right brainstem, and right cerebellum. Furthermore, the mean ReHo value in brainstem showed a positive correlation with the spasm severity ($r = 0.404$, $p = 0.027$), and the mean ReHo value in MFG was inversely related with spasm severity in HFS group ($r = -0.398$, $p = 0.028$). This study reveals that HFS is associated with abnormal spontaneous brain activity in brain regions most involved in motor control and blinking movement. The disturbances of spontaneous brain activity reflected by ReHo measurements may provide insights into the neurological pathophysiology of HFS. [9)].

Aneurysmal Subarachnoid Hemorrhage

The study of Maher et al. is the first examination of resting-state functional Magnetic Resonance

Imaging in a group of aSAH patients, used to characterize changes in functional connectivity of the frontoparietal network. We scanned 14 aSAH patients and 14 healthy controls, and divided patients into “impaired” and “unimpaired” groups based on a composite executive function score. Impaired patients exhibited significantly lower quality of life and neuropsychological impairment relative to controls, across multiple domains. Seed-based functional connectivity analysis demonstrated that unimpaired patients were not significantly different from controls, but impaired patients had increased frontoparietal connectivity. Patients evidenced increased frontoparietal connectivity as a function of decreased executive function and decreased mood (i.e. quality of life). In addition, T1 morphometric analysis demonstrated that these changes are not attributable to local cortical atrophy among aSAH patients. These results establish significant, reliable changes in the endogenous brain dynamics of aSAH patients, that are related to cognitive and mood outcomes [10].

MoyaMoya Disease

Results demonstrate distinct alterations in the temporal correlations of low-frequency BOLD signals, predominantly in resting-state networks in moyamoya disease. Additionally, Resting state functional magnetic resonance imaging (rs-fMRI) measures were associated with ischemic motor-related symptoms and cognitive performance in the patients. Thus, rs-fMRI may offer a useful non-invasive method of acquiring additional information beyond cerebral perfusion as part of clinical investigations in patients with moyamoya disease [11].

Idiopathic normal pressure hydrocephalus

Resting-state functional magnetic resonance imaging for idiopathic normal pressure hydrocephalus

Pediatric patients

Localizing neurologic function within the brain remains a significant challenge in clinical neurosurgery. Invasive mapping with direct electrocortical stimulation currently is the clinical gold standard but is impractical in young or cognitively delayed patients who are unable to reliably perform tasks. Resting state functional magnetic resonance imaging non-invasively identifies resting state networks without the need for task performance, hence, is well suited to pediatric patients. We compared sensorimotor network localization by resting state fMRI to cortical stimulation sensory and motor mapping in 16 pediatric patients aged 3.1 to 18.6 years. All had medically refractory epilepsy that required invasive electrographic monitoring and stimulation mapping. The resting state fMRI data were analyzed using a previously trained machine learning classifier that has previously been evaluated in adults. We report comparable functional localization by resting state fMRI compared to stimulation mapping. These results provide strong evidence for the utility of resting state functional imaging in the localization of sensorimotor cortex across a wide range of pediatric patients [12].

Case series

Resting state functional magnetic resonance imaging case series.

Unclassified

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