Functional magnetic resonance imaging

Functional magnetic resonance imaging or functional MRI (fMRI) is a functional neuroimaging procedure using MRI technology.

Types

Functional MRI (fMRI): consists of 2 types (task-based fMRI 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].

At present, presurgical functional mapping is the most prevalent clinical application of functional magnetic resonance imaging (fMRI).

Electroencephalography functional magnetic resonance imaging

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Advantages

fMRI for clinical routine is a reliable and rapid method for identification of functional brain areas prior to brain surgery adjacent to functional areas. This method allows direct monitoring of the data quality and visualization without being time consuming. Knowledge about the relation of functional areas to the brain lesions improves the preoperative planning, the operation strategy and decision making with patients [2].

Functional MRI (fMRI) can be used to measure neural activation by measurement of changes in blood oxygenation using the blood oxygen level dependent technique which is sensitive to local changes in the magnetic field induced by the presence of deoxygenated haemoglobin [3].

In a typical block-design application, the subject alternates between a passive resting state and performing a task. Clinical applications of task-based fMRI have focused on localizing areas of critical function for presurgical planning [4] and have been shown to correlate with intraoperative electrophysiology [5] Wada testing [6] and prediction of loss of function postoperatively [7].

Disadvantages

Despite its utility, task-based fMRI has several disadvantages that limit its application for preoperative functional localization.

Although it is a potentially powerful presurgical tool, fMRI can be fraught with artifacts, leading to interpretive errors, many of which are not fully accounted for in routinely applied correction methods.

The results are dependent on how well the patient can perform the prescribed task. In the setting of a brain tumor, cooperation and effective participation may be impaired due to neurological deficits or confusion [8]. Second, because the patient must be awake during the imaging procedure, sedation cannot be used. This often limits effective imaging in pediatric populations for whom conscious sedation is frequently necessary. Finally, task-based fMRI can be lengthy if multiple functional sites are interrogated in a single imaging session.

As an alternative to task-based fMRI, resting state functional magnetic resonance imaging (rs-fMRI) has been proposed as an imaging methodology for localizing critical sites independent of patient participation [9].

The addition of independent component analysis denoising of fMRI data in preoperative patients with glioma has a significant impact on data quality, resulting in reduced false-positives and an increase in true-positives compared with more commonly applied motion scrubbing or simple realignment methods [10].

Indications

Functional magnetic resonance imaging indications

1)
Yuh EL, Hawryluk GW, Manley GT. Imaging concus- sion: a review. Neurosurgery. 2014; 75 Suppl 4: S50–S63
2)
Mahvash M, Maslehaty H, Jansen O, Mehdorn HM, Petridis AK. Functional magnetic resonance imaging of motor and language for preoperative planning of neurosurgical procedures adjacent to functional areas. Clin Neurol Neurosurg. 2014 Aug;123:72-7. doi: 10.1016/j.clineuro.2014.05.011. Epub 2014 May 29. PubMed PMID: 25012016.
3)
Ward NS, Frackowiak RS. The functional anatomy of cerebral reorganisation after focal brain injury. J Physiol Paris 2006;99:425-36.
4)
Matthews PM, Honey GD, Bullmore ET. Applications of fMRI in translational medicine and clinical practice. Nat Rev Neurosci. 2006;7(9):732-744.
5)
Vlieger EJ, Majoie CB, Leenstra S, Den Heeten GJ. Functional magnetic resonance imaging for neurosurgical planning in neurooncology. Eur Radiol. 2004;14(7):1143-1153.
6)
Adcock JE, Wise RG, Oxbury JM, Oxbury SM, Matthews PM. Quantitative fMRI assessment of the differences in lateralization of language-related brain activation in patients with temporal lobe epilepsy. Neuroimage. 2003;18(2):423-438.
7)
Håberg A, Kvistad KA, Unsgård G, Haraldseth O. Preoperative blood oxygen level-dependent functional magnetic resonance imaging in patients with primary brain tumors: clinical application and outcome. Neurosurgery. 2004;54(4):902-914; discussion 914-905.
8)

Pujol J, Conesa G, Deus J, López-Obarrio L, Isamat F, Capdevila A. Clinical application of functional magnetic resonance imaging in presurgical identification of the central sulcus. J Neurosurg. 1998;88(5):863-869.
9)

Zhang D, Johnston JM, Fox MD, et al. Preoperative sensorimotor mapping in brain tumor patients using spontaneous fluctuations in neuronal activity imaged with functional magnetic resonance imaging: initial experience. Neurosurgery. 2009;65(6 suppl):226-236
10)

Middlebrooks EH, Frost CJ, Tuna IS, Schmalfuss IM, Rahman M, Old Crow A. Reduction of Motion Artifacts and Noise Using Independent Component Analysis in Task-Based Functional MRI for Preoperative Planning in Patients with Brain Tumor. AJNR Am J Neuroradiol. 2016 Nov 10. doi: 10.3174/ajnr.A4996. [Epub ahead of print] PubMed PMID: 28056453.