Atlas based seed analysis of resting state fMRI for pre-surgical brain mapping

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INTRODUCTION: Pre-operative localization of eloquent areas in the brain is extremely important in order to minimize the risk of post-operative loss of function. Task fMRI (t-fMRI) has been extensively and reliably used to assess proximity of functional areas to mass lesions prior to surgery[1]. However t-fMRI relies heavily on patient's cooperation and cognitive integrity. Resting state fMRI (rs-fMRI) is emerging as an alternative brain mapping method that is independent of patient's ability to comply with a task. It uses spontaneous oscillations of BOLD signal[2], which are synchronized within distinct functional networks. Some recent studies have attempted to demonstrate the feasibility of using rs-fMRI as a pre-surgical mapping tool[3,4,5], but it has yet to enter the routine clinical practice due to the complexity of post-processing needed to extract functional networks from the rs-fMRI data. Here we propose a simple method for processing rs-fMRI that meets the demands of clinical practice while reliably identifying functional networks.

METHODS: Participants: 16 healthy controls (8 female, age range: 18-33) and 30 patients (17 female; age range:19-63; tumor-13 patients, mesial temporal sclerosis-5 patient, vascular lesions-9 patients, other lesions-3 patients) referred for pre-surgical evaluation of language and motor function were enrolled in the study. A battery of language and motor tasks and a resting state (RS) scan were administered. All tasks were designed for clinical purpose and were presented visually. During RS scan, the subjects were asked to lie in the scanner with their eyes closed. Imaging data included a high-resolution T1 weighted structural image (TR=2350ms, TE=3.4ms, resolution 1x1x1mm^3) and a series of BOLD EPI scans (TR=3000ms, TE= 30ms, resolution 4x4x4mm^3). Data analysis was performed using the FSL software package. Activation maps for language and motor tasks were computed using General Linear Model. Eight network specific ROIs were created in classical language and motor areas using atlases available in FSL. The average time series from these ROIs were used to obtain activation maps showing the correlation between the ROI and the rest of the brain in healthy volunteers. These were compared to t-fMRI results. Three ROIs and their contralateral homologues were selected based on how well the resulting networks matched the t-fMRI networks in healthy volunteers. These were used for patient data analysis.

RESULTS: A comparison of functional networks generated from RS and t-fMRI in healthy volunteers, revealed the highest overlap for three RS ROIs: inferior frontal gyrus (pars triangularis and pars opercularis), superior temporal gyrus (posterior division), and primary motor cortex (BA4p). We found a high degree of overlap between RS and t-fMRI maps both when there was no lesion (Fig1) and when the lesion occupied functional space, in which case the contralateral hemisphere ROI was used (Fig 2).

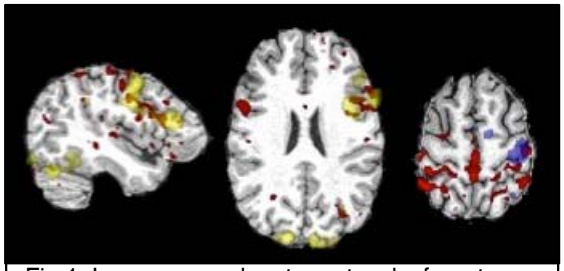

Fig 1. Language and motor networks from t-fMRI (yellow and blue) and rs-fMRI (red) in a patient with epilepsy.

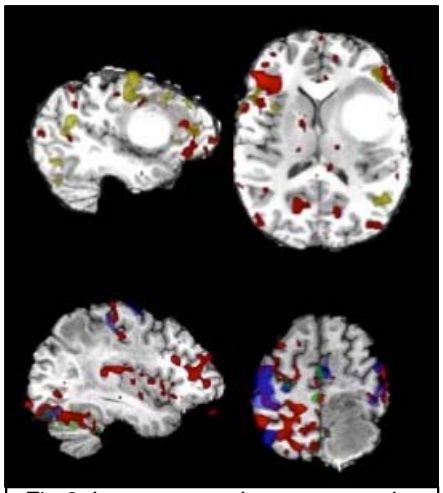

Fig 2. Language and motor networks from t-fMRI (yellow, blue, green) and rs-fMRI (red) in patients with lesions in or close to functional centers

CONCLUSION: We proposed a clinically feasible processing method of rs-fMRI analysis for pre-surgical planning that is not computationally intensive nor requires specialized expertise. We demonstrated that atlas based, operator independent selection of seeds can be used to map language and motor networks in patients with brain tumors or epilepsy. Although the rs-fMRI results were comparable to maps obtained using current t-fMRI clinical protocols, future research will have to validate these findings by comparing them with the gold standard intraoperative functional mapping and postsurgical clinical outcomes.

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