Identifying Brain Networks Using Single Pulse Electrical Stimulation (SPES) and Resting State Functional MRI Connectivity Analysis

Laszlo Entz MD; Stephan Bickel MD, PhD; Emilia Toth MS; Corey J Keller MS; Sharif Vakili; James Corines; Sara Stream; Sanjay Jain MD; Istvan Ulbert MD, PhD; Ashesh Mehta MD, PhD

Hofstra University School of Medicine, North Shore LIJ Health System and Cushings Neuroscience Institutes

CONGRESS OF NEUROLOGICAL SURGEONS 2011 ANNUAL MEETING WASHINGTON, DC OCTOBER 1-6, 2011

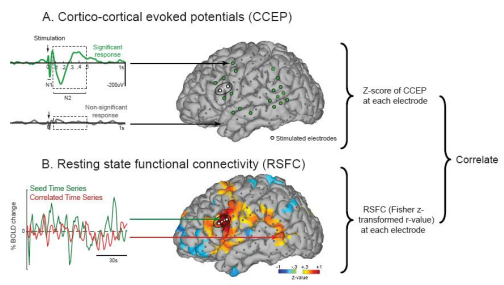
Introduction

Cortical brain areas are organized into networks that subsume both normal and pathological function. Mapping of these networks using correlated fluctuations of the blood oxygen level-dependent (BOLD) signal by functional connectivity analysis at rest (rfMRI) is a method used in the research arena to define brain networks involved in cognitive functions. However, the neurophysiological basis for these correlations remains unclear. Invasive electrode implantation for epilepsy surgery provides a means to probe these networks by cortical stimulation mapping in order to establish a neurophysiological basis and to define clinical utility.

Methods

8 patients undergoing intracranial electrode implantations were used as subjects for this study. Preoperatively, patients underwent rfMRI scans. After electrode implantation, bipolar stimulation was performed at each electrode pair using single pulse electrical currents (10mA, 0.5Hz, 0.2 msec) and the cortico-cortical evoked response (CCEP) was measured at all other contacts. Electrodes were localized using post-operative CT and MRI. In addition, stimulation mapping was performed along clinical guidelines to define language and sensorimotor areas. Seeds were placed over the fMRI regions corresponding to stimulated electrodes to determine fMRI z-scores.

Methods

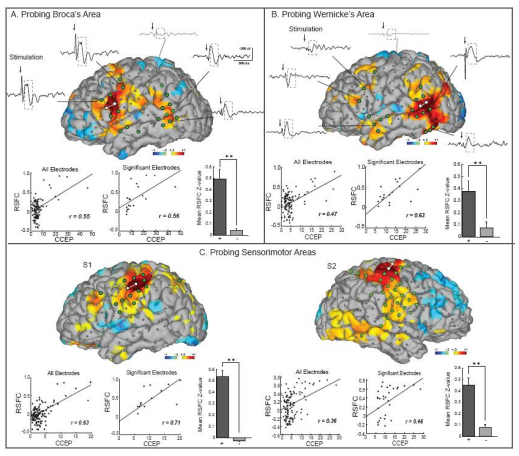


Correlation of CCEP and rsfMRI

Results

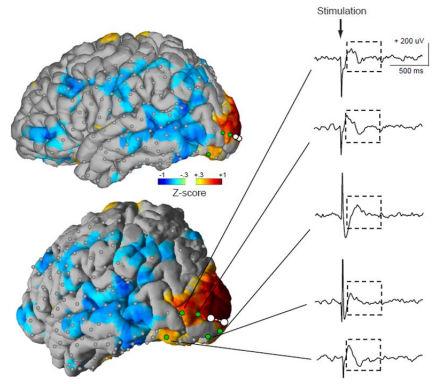
fMRI z-score and CCEP amplitude revealed a significant ($p<0.05$) correlation within and across subjects. Functional sensorimotor and language as well as pathological seizure networks were demonstrated using this approach.

Functional Networks



Correlation of CCEP and rsfMRI are shown for language and sensorimotor networks.

Pathological Networks

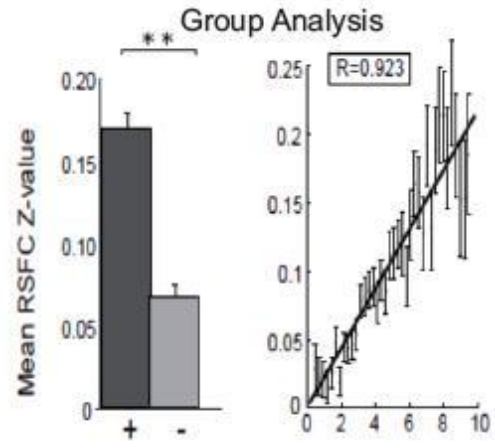


The Correlation of CCEP and rsfMRI is shown for the seizure onset newtork.

Conclusions

Our results show that networks defined by fMRI predict those defined by CCEP and have a neurophysiological basis. Furthermore, brain networks subsuming language and sensorimotor function as well as pathological networks involved in seizure spread can be mapped by these methods. Simirarly importantly this aids to reach higher accuracy in preoperative planning of tumor and epilepsy surgery near eloquent cortices with non-invasive techniques.

Summary RSFC and CCEP correlation



All stimulated electrodes in all subjects are shown

References

1. He BJ, Snyder AZ, Zempel JM, Smyth MD, & Raichle ME (2008) Electrophysiological correlates of the brain's intrinsic large-scale functional architecture. Proc Natl Acad Sci U S A 105:16039-16044.

2. Matsumoto R, et al. (2007) Functional connectivity in human cortical motor system: a cortico-cortical evoked potential study. Brain 130:181-197.

3. Fox MD & Raichle ME (2007) Spontaneous fluctuations in brain activity observed with functional magnetic resonance imaging. Nat Rev Neurosci 8:700-711.

4. Keller CJ, Bickel S, Entz L, Ulbert I, Kelley AM, Milham M and Mehta AD. 2011. Intrinsic Functional Architecture Predicts Electrically Evoked Responses in the Human Brain. Proceedings of the National Academy of Sciences (USA). 25:10308-10313.