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Coherence Analysis for Epilepsy Patients: An MEG Study

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***Abstract*—**It is crucial to quantitatively evaluate the treatment of epilepsy patients. This study was undertaken to test the hypothesis that compared to the healthy control subjects, the epilepsy patients have abnormal resting-state connectivity. In this study, we used the imaginary part of coherency to measure the resting-state connectivity. The analysis results shown that compared to the healthy control subjects, epilepsy patients tend to have abnormal rhythm brain connectivity over their epileptic focus.

***Keywords*—**Coherence, connectivity, resting-state, epilepsy

I. Introduction

FUNCTIONAL maps created with active state depend on subject's cooperation and on study paradigms that are capable of reliably activating the brain area of interest.

Instead of mapping brain area using activation methods, functional maps can also be created by measuring the functional connectivity under resting-state. The underlying rationale is that disconnected tissue does not participate in the brain interactions occurring between brain areas and would show abnormal functional connectivity. Temporal connectivity under resting-state are presumed to reflect intrinsic functional connectivity and have been demonstrated across several distinct networks serving critical functions like vision, hearing, language, and salience detection [1]-[3]. One such network that has been studied extensively is the default mode network (DMN), a set of brain regions that typically deactivate during performance of cognitive tasks [4]. Detection of temporal connectivity in resting-state network would provide more compelling evidence for the existence of a default mode network, and enhance the understanding of neural activity in baseline states, thereby refining interpretations of ''activation'' and ''deactivation'' in functional imaging studies [5]. Some studies demonstrated that the strength of resting-state functional connectivity reflects the strength of structural connectivity [6][7].

Some pioneering electroencephalographic (EEG) and magnetoencephalography (MEG) studies assessing functional connectivity in patients with brain lesions using coherence found highly significant decrease in coherence in lesion patients during the resting state [8][9]. However, since the traditional coherence method is sensitive to volume conduction artifact [10], functional connectivity is easily overestimated. Recently, Nolte et al. [11] introduced imaginary part of coherence to overcome such problem.

In this study, we tried to use imaginary part of coherence to compare the functional connectivity in epilepsy patients and healthy control subjects.

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II. Subjects And Methods

A. Patients and Healthy Control Subjects

10 epilepsy patients and 10 healthy control subjects underwent MEG and fMRI scan at the Nanjing Brian Hospital (NBH), Nanjing Medical University. All participants gave their written informed consent to participate in the experiments; all procedures were approved by NBH Committee on Human Research.

B. Magnetoencephalographic Recordings

The participants were laying awake and with their eyes closed in a magnetically shielded room while their continuous resting state MEG was recorded with a 275-channel whole-head MEG system (VSM MedTech, Canada), using a sampling rate of 300 Hz. An artifact-free epoch of 2-minute duration was recorded for subsequent analysis in each patient and subject.

C. Imaginary Coherence

The coherence, measures the linear time-invariant relationship between two time series x(t) and y(t) at frequency λ, is defined as

$$Coh_{xy}(\lambda) = \left|R_{xy}(\lambda)\right|^2 = \left|\frac{f_{xy}(\lambda)}{\sqrt{f_{xx}(\lambda)f_{yy}(\lambda)}}\right|^2 \tag{1}$$

Where $Rxy(\lambda)$ is the complex valued coherency of x and y, $fxy(\lambda)$ is the cross-power spectral density (CPSD) of x and y, and $fxx(\lambda)$ is the power spectral density (PSD) of x . Coherence is a positive function, and bounded by 0 and 1, where 0 indicates that x and y have no linear relationship, and 1 indicates that x and y have perfect linear relationship.

A 60 s duration raw MEG data was selected for subsequent analysis in each patient and subject. The raw MEG data were high-pass filtered with a cut-off frequency of 4 Hz and notch filtered at 50 Hz. CPSD of x and y was computed by using Welch's method [13]. The Fourier-transformed $X(\lambda)$ and $Y(\lambda)$ are used to compute the CPSD, $fxy(\lambda) = X(\lambda) Y^*(\lambda)$, where Y^* denotes the complex conjugate of Y. X and Y were Hanning-windowed, each segment k was 2 s long and overlapped adjacent segments by 1 s. Finally, fxy is averaged over the whole successive segments.

After calculating the complex valued coherence, then took the square value of the imaginary part of complex valued coherence as the imaginary coherence (IC):

$$IC_{xy}(\lambda) = \left| \text{imag}[R_{xy}(\lambda)] \right|^2 \qquad (2)$$

All of the data analyses were performed using custom programs written in Matlab R2010a (Mathworks Inc., Natick, MA, USA).

III. Results

Fig.1 shows the typical results for 2 patients and healthy control subjects:

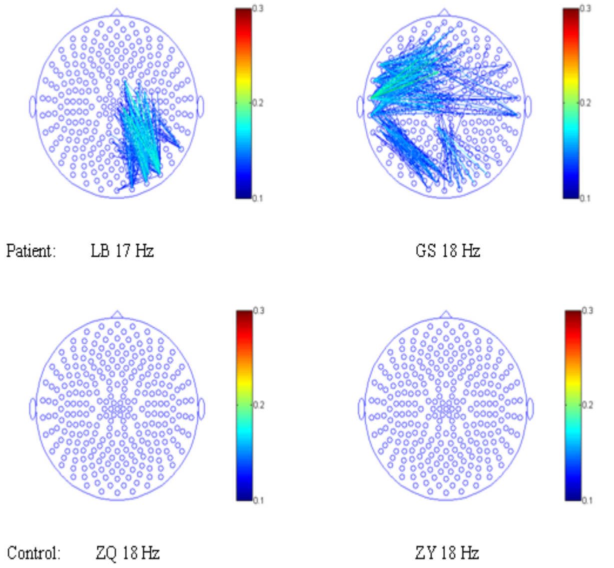

Fig.1 Patterns of imaginary coherence connectivity increased in the β band for patients than healthy control subjects (values below low threshold=0.1 will not be shown in the figure, while values beyond high threshold=0.3 will be shown as red line)

The MEG analysis for patients LB and GS shown MEG epileptic dipoles at right occipital lobe and left frontal lobe, respectively. According to the patterns of imaginary coherence connectivity shown in Fig.1, there is increased connectivity around 18 Hz over epileptic dipole locations for these two patients. However, there is no obvious connectivity for two healthy control subjects ZQ and ZY.

IV. Discussion

Unlike previous coherence studies [8][9], which shown decreased connectivity over lesion locations, this study shown increased connectivity over epileptic focus. One reasonable explanation is that the previous studies investigated brain lesions (space-occupying brain lesions for [8], and brain tumors for [9]), the presence of lesions disrupting cortex and adjacent white matter the coherence between those areas and the remaining cortical areas are lower than normal due to impairment of the fibers that connect the damaged areas with the rest of the brain. Although, the definite cause for epilepsy is not clear yet, unlike the space-occupying or necrosis tissues, some epilepsy cases have normal tissue structure [14] but characteristically abnormal rhythm which produced by excessive electrical discharges in the nerve cells. Our analysis results, in some extent, reflect this phenomenon, i.e., compared to the healthy control subjects, epilepsy patients tend to have abnormal rhythm brain connectivity over their epileptic focus.

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