Automatic Drawing of Correct Topographical Distribution of EEG Rhythms Based on Unified Suitable Reference Selection

Bei Wang[1], Xingyu Wang[1], Akio Ikeda[2], Takashi Nagamine[3], Hiroshi Shibasaki[4], Masatoshi Nakamura[5]

[1]*Key Laboratory of Advanced Control and Optimization for Chemical Processes, College of Information Science and Technology, East China University of Science and Technology, Shanghai 200237, China*
[2]*Department of Neurology, Kyoto University, Kyoto 606-8501, Japan*
[3]*Department of System Neuroscience, Sapporo Medical University, Hokkaido 060-8556, Japan*
[4]*Takeda General Hospital, Kyoto 601-1495, Japan*
[5]*Research Institute of Systems Control Institute for Advanced Research and Education, Saga University, Saga 840-0047, Japan*
(Tel: 86-21-64253581; Fax: 86-21-64253386)
(beiwang@ecust.edu.cn)

***Abstract*:** Electroencephalography (EEG) interpretation is important for brain diseases inspection. In this study, an automatic technique was developed to realize the automatic drawing of correct topographical distribution of EEG rhythms, which would be an assistant tool for EEG interpretation. Unified suitable reference electrode was selected automatically to construct the common referential derivation. Topographies were drawn according to the amplitudes of EEG rhythms calculated among the scalp of head. The final result of topographical distribution was helpful to highlight the EEG rhythms of interest for automatic EEG interpretation. The developed technique has application significance for real clinics.

Keywords: Topographical distribution, EEG rhythm, Reference selection, Automatic EEG interpretation

I. INTRODUCTION

The electroencephalogram (EEG) waveforms are generally described by kinds of rhythms according to the frequency, amplitude and shape. The interpretation on the distribution of EEG rhythms had clinical significance for brain diseases inspection, when the normal properties of EEG rhythms were becoming abnormal.

An automatic EEG interpretation system had been applied for real clinics. The relative EEG potential between the recorded electrode position and the reference were analyzed to judge the grade of normality or abnormality of awake EEG records [1] [2]. The EEG waveform under different reference potentials, which was called derivations, could bring different results. When the reference was contaminated by artifacts, the derived EEG waveform would be unsuitable for automatic interpretation. Therefore, the selection of reference was important to obtain correct EEG interpretation result.

In this study, an automatic technique was developed to realize the automatic drawing of correct topographical distribution of EEG rhythms based on unified suitable reference electrode. The ultimate purpose was to obtain the correct interpretation result for clinical practice. The reference was selected based on an iterative method, to construct the common referential derivation. The obtained EEG waveforms and periodograms under common referential derivation were analyzed. The amplitudes of EEG rhythms were calculated among the scalp of head based on the common referential derivation. Finally, the obtained topographical distributions of EEG rhythms were evaluated comparing with the visual inspection.

II. METHOD

1. Data acquisition and visual inspection

The EEG data of one patient suffered by brain disease was analyzed. The data was recorded at Kyoto University, Japan. According to the International 10-20 System [3], totally 19 channels of EEG waveforms were recorded including Fp1, F3, C3, P3, O1, Fp2, F4, C4, P4, O2, F7, T3, T5, F8, T4, T6, FZ, CZ and PZ which covered the scalp of head. Another 2 channels recorded at left and right ear-lobes of A1 and A2. The recording was done with the time constant of 0.3 s, the high cut filter of 120 Hz and a sensitivity of 0.5 cm/50μV. The sampling rate was 200 Hz for all the channels. The long

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EEG record was divided into consecutive segments of 5- second long each for analysis.

The recorded data was inspected by a qualified clinician, especially the EEG rhythms distribution. The EEG waveform of test subject was moderately abnormal. There were 'continuous irregular slow wave more on the right posteriorly and can be a localized slow wave in the right midtemporal (T4) to central (C4) region'.

2. Automatic reference selection

An iterative method had been developed to find out the unified suitable reference for EEG interpretation. The flowchart of automatic reference selection was illustrated in Fig. 1.

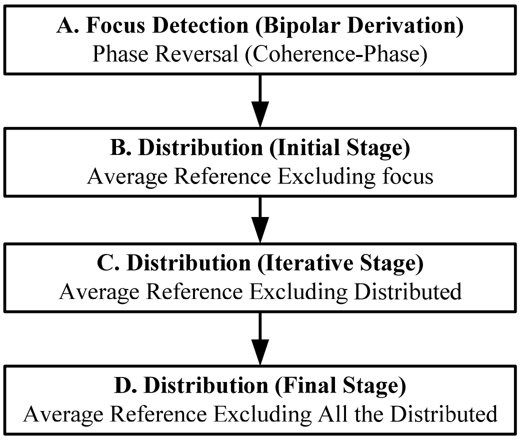

Fig.1. Flowchart of automatic reference selection

There were four main steps. Firstly, the cross-spectrum of bipolar EEG was adopted to detect the focus of EEG rhythm as step A. Under the bipolar derivation, the reference was the neighbor electrode. The cross-spectrum showed the relation of two bipolar EEGs. Parameters of coherence and phase were calculated to analyze phase reversal. The detected phase reversal area corresponded to the focus of EEG rhythm. In step B, C and D, the distribution of amplitude of EEG rhythm was analyzed to detect the distributed area among the scalp of head. Finally, a unified suitable reference was selected excluding all the distributed electrodes. The detail algorithm was described in [4].

3. Topographical distribution of EEG rhythms

A. Referential derivation construction

The 16 channels of EEG waveforms, Fp1, F3, C3, P3, O1, Fp2, F4, C4, P4, O2, F7, T3, T5, F8, T4, and T6 covering left and right hemisphere, were obtained by taking the relative potential of each electrode with the selected unified reference.

B. Distribution of amplitude of EEG rhythm

Fast Fourier Transformation (FFT) was taken for the EEG waveform under the constructed referential derivation. According to the sampling rate, the data length of each 5-second segment was 1000 points. By taking 1024-point FFT, the frequency resolution of peirodogram was 0.2 Hz. The amplitude of EEG rhythm was calculated by

$$A(f) = 4\sqrt{S(f)}\,, \qquad (1)$$

where S was the amount of power within the frequency band of EEG rhythm.

C. EEG rhythm separation

The obtained amplitude value for totally 16 channels indicated the topographical distribution of EEG rhythm among the scalp of head. A band pass filter was utilized to extract the EEG rhythm component from the EEG waveform to evaluate the consistency between the automatic result and visual inspection.

III. RESULTS

1. Unified suitable reference selection

The EEG data of one 5-second segment was analyzed. Based on the original EEG data from EEG recorder, bipolar derivation was constructed. The cross-spectrum of slow wave 0.5-8 Hz was analyzed for both horizontal and vertical directions of bipolar EEG.

The result of cross-spectrum analysis for phase reversal detection was illustrated in Fig. 2. The left side was cross-spectrum, coherence and phase for horizontal bipolar EEG. The right side was the cross-spectrum,

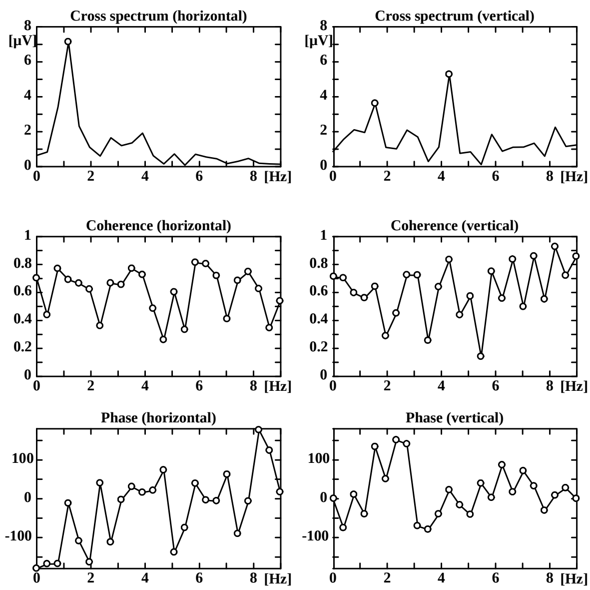

Fig.2. Cross-spectrums of bipolar EEG

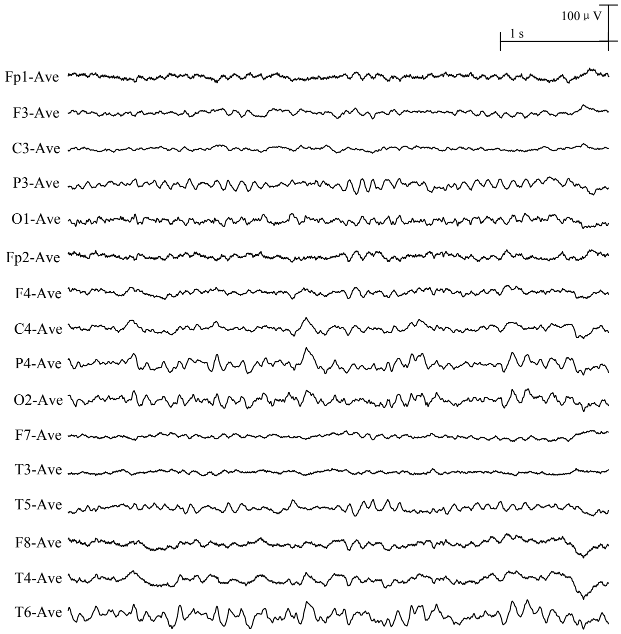

Fig.3. EEG waveforms under referential derivation

coherence and phase for vertical bipolar EEG. For the test subject, T4 was detected automatically as the focus. By using the iterative method, F8, C4, P4, O2 and T6 were detected as the distributed area.

Finally, the automatically selected reference was the average potential of all electrodes excluding T4, F8, C4, P4, O2 and T6. The EEG waveform under the new constructed referential derivation was shown in Fig. 3.

2. Periodograms analysis

The periodogram of the EEG waveform shown in Fig. 2 was obtained by taking 1024-point FFT. The periodograms were illustrated in Fig. 4. For each channel, the power of frequency band from 0.5 to 25 Hz was displayed. The frequency band from 0.5 to 25 Hz covered the main activities of EEG rhythms. The slow wave from 0.5 to 8 Hz was marked by grey color. The scale of each peirodogram was the same and the amount of slow wave can be observed among the scalp of head. The empty circles indicated the automatically detected peaks within the slow wave frequency band. The detected peaks would be utilized for EEG rhythm separation.

3. Topographical distribution of EEG rhythms

According to the peridogram, the amplitude of slow wave from 0.5 to 8Hz was calculated for each channel. The amplitude values were shown as the topographical distribution of EEG rhythm of slow wave. Comparing with other channels, the lager amplitude values can be

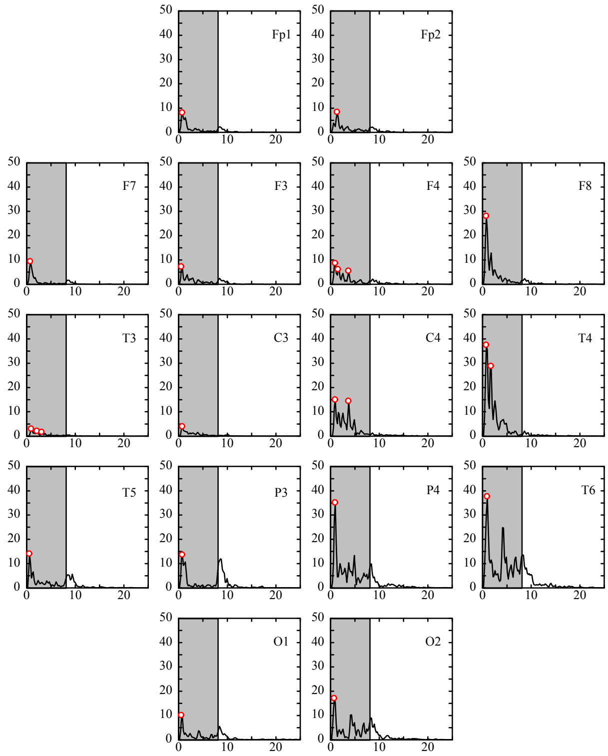

Fig.4. Periodograms.

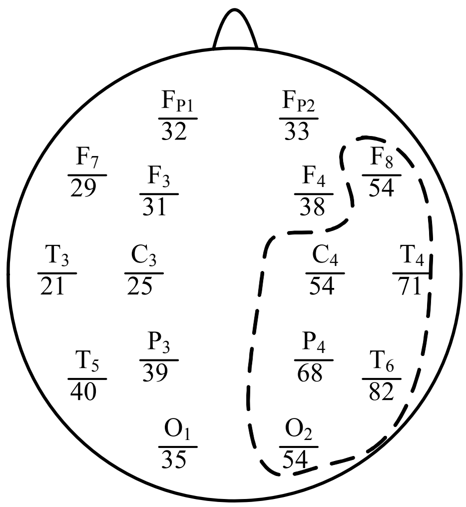

Fig.5. Topographical distribution of EEG rhythm of slow wave among the 16 EEG channels.

observed at the dotted area of focus T4 and distributed F8, C4, P4, O2 and T6 in Fig. 5.

Furthermore, the detected peaks in periodograms showed that the distributed slow wave frequency was lower than 4 Hz. A band pass filter of FFT-IFFT was adopted to separate the frequency activity from 0.5 Hz to 4 Hz out of the EEG waveforms. The separated results were illustrated in Fig. 6. It can be observed that

T4, F8, C4, P4, O2 and T6 had obvious slow wave. The separated results were consistent with the visual inspection.

IV. DISCUSSION

1. Unified suitable reference selection

The visual inspection on EEG interpretation is a critical skill for neurologists. Automatic EEG interpretation had been developed which can bring subjective inspection result as an assistant tool for clinical practice. The reference selection problem was important for both visual inspection and automatic interpretation. When the reference was unproper or contaminated by artifacts, the derived EEG waveform would affect the interpretation result. In this study, we investigated on the reference selection for automatic interpretation. Focus was detected by cross-spectrum of bipolar EEG and distributed area was detected by considering the distribution of EEG rhythm among the scalp. The obtained unified suitable reference can highlight the EEG rhythm of interest and bring correct interpretation result.

2. Topographical distribution of EEG rhythms

According to the selected unified suitable reference, an automatic drawing method for topographical distribution of EEG rhythm was developed. The amplitude of EEG rhythm was calculated for each channel. Band pass filter was adopted to separate EEG rhythm according to the peaks in periodogram. The topographical distribution can be observed based on the amplitude values. The separated waveform can reflect the frequency property of the distributed EEG rhythm. The obtained result highlighted the EEG rhythm of interest and was fit to the visual inspection. For the test subject, the peaks in the periodogram were rather closed. According to the brain diseases, there may be several peak groups in other case. Further proper separation of EEG rhythms would be developed as the future works

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V. CONCLUSION

The automatic drawing of topographical distribution of EEG rhythm was investigated. The main method was based on a unified reference selection technique. The obtained automatic result was consistent with visual inspection. The developed technique had clinical application for EEG interpretation.

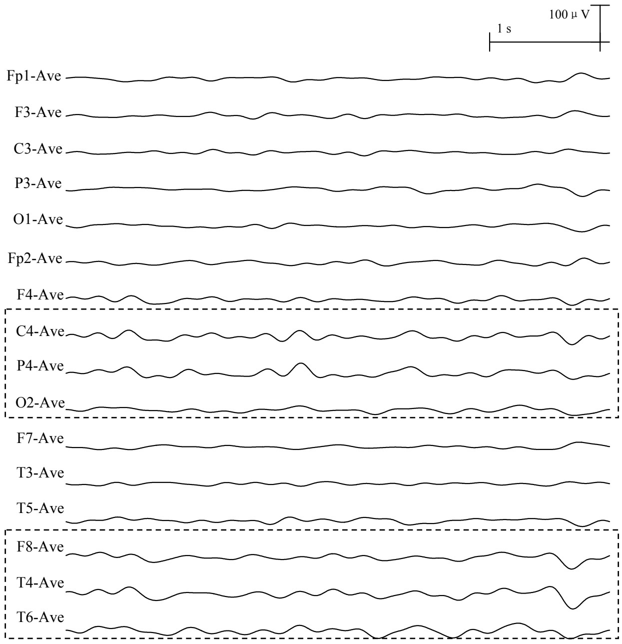

Fig.6. Separated EEG rhythm from 0.5 to 4 Hz.

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