

Evaluations of dementia by EEG frequency analysis and psychological examination

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Abstract In order to evaluate the stage of dementia, we focused attention on EEG rhythms and Hasegawa-dementia-rating scale (HDS-R). Frontal EEGs were recorded from dementia patients and normal controls during music and photo-image stimulations, and frequency analysis was performed. In the controls, profiles of rhythm pattern during music stimulation seemed to be markedly different from those during photo-image stimulation. In contrast, in dementia patients, it was difficult to find those differences. Interestingly, as HDS-R decreases, the variability of rhythm patterns also decreases. These results suggest that a decrease in cognitive function might be related to a decrease in the ability to generate various cortical rhythm patterns.

Keywords EEG · Frequency analysis · Dementia · HDS-R · Music · Photo image · Theta frequency band · Alpha frequency band

Introduction

Dementia is considered to be a disease of cognitive dysfunction, but not to be an exaggerated condition of normal

aging [9, 10]. Dementia has several stages of cognitive dysfunction, and has the feature of gradual exacerbation. Mild cognitive impairment (MCI) tends to convert into dementia, and once suffering from the dementia, it is difficult to improve cognitive function [11, 14]. Therefore, it is important to diagnose the early stage of cognitive dysfunction for prevention and treatment of dementia.

In order to evaluate dementia, Hasegawa-dementia-rating scale (HDS-R) and mini-mental state examination (MMSE) have been developed, and are generally used, as in psychometric assessment. Recently, for morphological and metabolic assessments, diagnostic criteria have been under development by using brain-imaging techniques, such as functional MRI and FDG-PET [7, 10]. These methods enable us to investigate from the surface to deep areas of the brain, and to provide information about regional atrophy and homodynamic changes. However, these medical examinations may to some extent impose stress on the patients. Among electrophysiological methods, evaluations of cognitive dysfunction by using event-related potential (ERPs) or electroencephalographic (EEG) frequency analysis have been developed [1, 6]. Although electrophysiological activities reflect neuron activities in the brain, it is presently difficult to evaluate precise stages of dementia.

For screening cognitive dysfunction, less invasive and less stressful examinations that reflect brain function are preferred. In this respect, we have focused attention on EEG frequency analysis, and psychological assessment, HDS-R, in the present study.

Methods

Sixteen outpatients, whose ages were 73.7 ± 4.8 years (mean \pm SD), from Kanazawa Medical University

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Hospital, diagnosed as having dementia were included in this study. All patients underwent the psychological test of HDS-R. A medical doctor of geriatrics performed the psychological test. Ten healthy controls whose ages were 58.0 ± 13.8 years (mean \pm SD) were recruited, and also underwent the neuropsychological test of HDS-R. All experiments were undertaken with the understanding of the subjects.

EEGs were recorded from frontal region of the scalp, by using EEG recorder, FM-515A (Futek, Tokyo, Japan). Frequency analyses of EEGs were performed with PRLUXII (Futek). Frequency bands were divided into theta (4–7 Hz), alpha1 (7–9 Hz), alpha2 (9–11 Hz), alpha3 (11–13 Hz) and beta (13–30 Hz). Data were collected for every 1 s. Occupancy rate of each frequency band was calculated as follows. Power of each frequency band was divided by the sum of the powers of all frequency bands, and the ratio was defined as a unit occupancy rate (%). Activities of each frequency band were firstly assessed by the unit occupancy rate per second. Then the unit occupancy rates through one course of session (180 s) were averaged, and we adopted the data of “occupancy rate” (%). Hereafter in this study, we refer to the averaged rate as occupancy rate.

Participants sit in the body sonic chair (Refresh 1 Excellent, Tokyo, Japan), and listen to the music in comfort. In front of the chair, a 150 cm \times 100 cm screen was located at 2 m distance on which patients were able to see images of photographs. Images were projected on the screen through a PC Projector, EMP-1705 (Epson, Tokyo, Japan) connected to a PC. Famous Japanese standard songs in the category of country music, “Furusato” and “Nanatsuno-ko”, were selected from Japanese music CDs, and presented as an auditory stimulation. Photographs of scenic Japanese spots were presented as visual stimulation. The auditory and visual stimulation were applied for 180 s each.

During one session (180 s), EEG epochs with artifacts were identified (threshold: 5 μ V), and artifact-free EEG epochs were adopted for analysis. Thus, the “unit occupancy rate” through one session was not 180 but 154.3 ± 21.5 (mean \pm SD, $n = 16$) in the case of the auditory stimulation for dementia patients, 133.8 ± 31.7 (mean \pm SD, $n = 16$) in the case of visual stimulation for dementia patients, 163.8 ± 14.6 (mean \pm SD, $n = 10$) in case of auditory stimulation for healthy controls, and 156.9 ± 26.8 (mean \pm SD, $n = 10$) in case of visual stimulation for healthy controls.

Local institutional ethics committees of Kanazawa Medical University approved the present study, and all experiments were performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and the Guiding Principles for the Care and Use of Animals in the Field of Physiological Sciences. All persons gave their informed consent prior to their inclusion in the study.

Results

EEGs were recorded from a healthy control during both music and photo-image stimulations, and frequency analysis was performed. The occupancy rate of each frequency band is shown in Fig. 1a. In the case of the music stimulation, the occupancy rate of the alpha2 band was dominant compared with those of other frequency bands, whereas in the case of the photo-image stimulation, the occupancy rates of the theta and beta bands were relatively dominant compared with those of other frequency bands. The profiles of the rhythm pattern during music stimulation and during photo-image stimulation seemed to be markedly different.

In the same way, EEGs were recorded from a dementia patient during both music and photo-image stimulation, and frequency analysis was performed. The occupancy rate of each frequency band is shown in Fig. 1b. On comparing the occupancy rates of the five frequency bands obtained from a dementia patient with those obtained from a healthy control, it is difficult to find marked differences of rhythm pattern in the dementia patient (Fig. 1b). These results show that different patterns of frontal EEG rhythm seem to be generated in a normal control when different sensory stimulations are applied, whereas, in a dementia patient, it might be difficult to generate diverse patterns of frontal EEG rhythm.

Occupancy rates of theta frequency bands obtained from 10 normal controls are plotted together in Fig. 2a (Theta), and those obtained from 16 dementia patients are plotted together in Fig. 2b (Theta). In the same way, occupancy rates of other frequency bands are plotted in Fig. 2a, b. By comparing the occupancy rates obtained from normal with those obtained from dementia patients, occupancy rates elicited by music stimulation in normal controls tended to be different from those elicited by photo-image stimulation in a few frequency bands, whereas, in dementia patients, it is difficult to find differences of occupancy rates between the music and photo-image stimulations. These findings are statistically evaluated as follows.

In order to quantify the variability of rhythm patterns, the variation score of each frequency band was obtained by subtracting the occupancy rate in the case of photo-image stimulations from the occupancy rate in the case of music stimulations, which was executed for the five frequency bands. The data obtained from individual subjects were averaged, and are plotted in Fig. 3. In this figure, the variation score near zero indicates that there is a small difference between the occupancy rate during music stimulation and that during photo-image stimulation. Analysis of variance (ANOVA) was used to evaluate the statistical significance of the variation scores in all five frequency-bands. In the dementia group, there is no statistical difference ($F = 2.67$, $P = 0.038$), whereas in the normal group, there