Electroencephalogram Analysis to determine the Signal Location Originated from Cerebral Cortex of the Patient with Early Alzheimer's disease

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Abstract: Determination of the signal originated from cerebral cortex embedded into the electroencephalogram (EEG) spectrum of the patients with early Alzheimer's disease is developed. Five Alzheimer's disease patients were participated the clinical trial, which was approved by the local IRB, as the trial group. Meanwhile, five normal control subjects were also included as normal group. Short Term Fourier Transform (STFT) was applied for the measured EEG spectrum of the patients to determine the characteristic frequencies and the reaction time embedded in EEG spectrum. The analyzed result indicated that a unique frequency caused by the localized physical pathogen of Alzheimer's disease can be realized in cerebral cortex by STFT EEG analysis.
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Introduction

In this study, we define the physical pathogen of Alzheimer's disease (AD) as a specific localized bundle of nerve cells that are responsible for the dementia of the patients with Alzheimer's disease. Dementia is the cardinal syndrome of significant loss in memory and cognitive impairments of sufficient severity to interfere with social or occupational functioning. AD is the most common cause of dementia in the elderly. An impairment of learning and memory is usually observed for AD patients but declarative memory being most affected besides some semantic difficulties. The electroencephalogram (EEG) has been used as a tool for diagnosing AD for several decades. It was revealed EEG abnormalities in AD patients specifies a shift of the power spectrum to lower frequencies and a decrease in coherence of fast rhythms. These abnormalities are thought to be associated with functional disconnections among cortical areas resulting from death of cortical neurons, axonal pathology, cholinergic deficits, etc. In this paper, we applied a non-linear time series modeling technique STFT to analyze the data collected from the EEG of the subjects. From previous study **[1]**, it was suggested that brains afflicted by Alzheimer's disease show behaviors which are less chaotic than those of normal healthy brains. Since EEG data is highly nonlinear and varies with times, it changes abruptly when an interference was occurred. The purpose for this study, in clinical, is to develop a simple and easy convincible analysis for EEG of the patients with AD.

Analysis Algorithm

The analysis algorithm is based upon principle component analysis (PCA) and the STFT at different characteristic frequencies. Fifteen possible parameters D1, D2, D3,…., D15 should be determined first through the method of embedding dimension. And then, together with principle component analysis of the STFT of EEG of the patient with AD at 5Hz and the regression analysis of D, the specified distance between electrode and the AD physical pathogen can be determined. In Table I, it is listed the D values which were embedded in EEG spectrum. The possibility contributions of D to its components of the STFT of EEG for the patient with AD at 5Hz (θ wave) is demonstrated in Table II. Since each electrode of the EEG equipment can collect more than 100,000 data in 10 minutes at the sample rate of 1/20 for the patient, the D values are determined via the method of embedded dimension [2] and Heisenberg theory [3]. The dimensions of D could be reduced from 140,000 to 15 for this study. In Table III, it has shown the intensity of the 5Hz signal being determined from STFT of EEG at different electrodes. In Table IV, it is shown the linear regression analysis of the D parameter.

Table I. D value is the distance between electrode and the location of possible AD pathogen (mm)

D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
0.00	0.07	0.10	0.12	0.14	0.15	0.17	0.18	0.20	0.21	0.22	0.23	0.24	0.25	0.26

Table II. The possibility contributions of D to its Components of the STFT of EEG for the patient with AD at 5Hz (θ wave)

	Components			
Parameters	1	2	3	4
D1	.495	.622	-.493	-.147
D2	.427	-.301	.470	.465
D3	.210	-.752	.096	.224
D4	.884	-.328	.014	-.011
D5	.939	.036	-.264	.031
D6	.953	.053	-.106	.126
D7	.622	.135	.634	-.068
D8	.755	.001	.587	-.096
D9	.932	.267	-.074	-.044
D10	.721	-.462	-.349	.072
D11	.109	.682	.600	.057
D12	-.515	.318	.050	.581
D13	.400	.066	-.307	.672
D14	.865	.293	-.088	-.207
D15	.014	-.592	.114	-.397

Table III. Intensity of EEG of D via electrode for the patient with AD at 5Hz (θ wave)

	D1	D2	D3	D4	D5	D6	D7	D8	D9	D10	D11	D12	D13	D14	D15
C3	0.35	0.97	0.8	2.75	1.59	0.41	3.52	3.33	0.85	0.45	3.08	1.55	2.03	2.31	0.37
C4	0.13	3.19	5.46	1.4	0.76	0.14	2.41	2.55	0.28	0.41	1.92	0.95	0.82	4.59	5.7
F3	0.43	0.44	0.36	3.23	1.99	1.42	10.51	3.6	3.5	0.02	6.79	1.76	3.57	3.44	1.27
F4	0.13	4.06	7.94	12.64	0.62	0.71	17.15	10.14	2.95	0.11	5.78	0.43	1.22	4.99	4.16
F7	1.21	0.31	0.31	2.7	1.31	0.6	8.36	1.99	4.42	0.25	6.97	0.03	2.35	4.81	1.58
F8	0.01	2.9	1.47	10.46	1.26	0.2	8.4	5.42	3.68	0.07	3.87	0.26	0.8	3.76	4.37
FP1	1.92	0.07	4.21	22.16	18.52	5.09	8.86	5.47	17.05	2.85	2.02	0.08	3.49	16.25	1.45
FP2	0.31	13.74	5.4	28.15	17.49	6.09	17.75	13.6	16.04	3.91	4.58	0.02	2.52	13.58	3.31
O1	0.4	2.92	1.32	5.76	2.11	1.13	0.46	2.56	0.32	1.71	1.98	0.54	0.07	3.91	0.52
O2	0.08	1.87	6.41	8.27	4.21	1.31	1.11	0.01	0.51	1.37	0.99	0.2	2.42	0.47	5.34
P3	0.11	6.69	5.58	24.9	4.53	2.37	7.45	5.49	1.95	3.36	0.03	0.19	3.22	0.55	2.26
P4	0.1	0.01	7.82	11.05	3.42	0.47	3.86	1.35	0.97	2.48	0.87	0.62	3.01	2.26	5.27
T3	0.12	11.8	7.28	2.73	1.44	0.97	3.62	1.19	1.6	0.21	4.06	1.22	3.27	0.15	0.33
T4	0.16	2.08	0.63	0.05	0.95	0.42	5.74	1.5	2.01	0.63	0.42	0.84	0.86	0.5	2.54
T5	0.04	2.19	3.9	8.98	0.6	0.96	9.19	3.61	0.36	0.97	3.74	0.09	0.61	0.8	0.55
T6	0.04	1.53	7.38	7.57	1.31	0.13	8.87	1.58	0.47	2.03	0.47	0.56	2.18	1.83	2.42

Table IV. Regression model of D via the D1, D3, D5 and D6

		Non-standardized		standardized	T	Significance
		B	error	Beta		
Model	constant	-.362	.077		-4.695	.001
	D5	.252	.024	1.421	10.377	.000
	D1	.416	.095	.212	4.383	.001
	D6	-.356	.071	-.620	-5.030	.000
	D3	-.063	.013	-.182	-4.759	.001

Table V. The Signal 5Hz was found D mm from FP2 electrode

	D (mm)	
Position of electrode	Trial group D_t	Normal group D_n
C3	0.40	0.09
C4	0.39	0.26
F3	0.38	0.28
F4	0.40	0.16
F7	0.40	0.42
F8	0.38	0.08
FP1	0.39	0.12
FP2	0.39	0.16
O1	0.40	0.19
O2	0.38	0.33
P3	0.40	0.32
P4	0.39	0.28
T3	0.39	0.26
T4	0.39	0.22
T5	0.40	0.25

Results And Discussions

From Table II, by the highest contribution coefficient 0.953 at D6 is 0.15mm, the top two values of measured 5 Hz signal at electrode FP1 and FP2 are 5.09 μVolt and 6.09 μVolt are shown in Table III. By the second highest contribution coefficient 0.939 at D5 is 0.14 mm, measured 5 Hz signal at electrode FP1 and FP2 is 18.52μVolt and 17.49 μVolt. The most probable D value for the subjects in trial group, $D=D_t$, therefore is shown in Eq. (1) from Regression Model.

$$D_t = \left| -.362 - .063*D3 + .252*D5 - .356*D6 \right| \quad \textbf{Eq. (1)}$$

From Eq. (1), we can calculate the D value of 5Hz signal which may be originated from physical pathogen of the patient with AD.

Meanwhile, the most probable D value for the subjects in normal group, $D=D_n$ is shown in Eq.2 from Regression Model as well.

$$D_n = \left| .063*D3 + .248*D5 + .360*D6 \right| \quad \textbf{Eq. (2)}$$

Since the early detection of subjects with probable Alzheimer's disease (AD) is critical for treatment strategies [4]. The ability of a multitude of linear and non-linear analysis algorithms to discriminate between the EEG of patients with varying degree of associated AD parameters for the control subjects is a major concern. Absolute and relative spectral power, distribution of spectral power, and measures of spatial synchronization were calculated from recordings EEG were previously investigated [5,6]. In this report, we provide the preliminary study for early AD predictive model. Further research and the evidence in comparison with the fMRI should be carefully designed and conducted. The regression calculation results are demonstrated in Table V.

Conclusion

The average trial group D_t value of D is 0.39 mm, which means physical pathogen 5Hz signal was originated 0.39 mm from FP2 electrode in Cerebral Cortex. The EEG average value of the D by STFT and PCA analysis for all the subjects in all channels are listed in Table V. The D value, D_t at lead Fp2 of the patient in trial group is more invariant than the D values, D_n for the subjects in normal group. Investigation has shown that our optimal embedding method is faster and more accurate than the conventional procedures in the present time. It may be useful for estimating the non-linear invariant measurements of EEG to diagnose Alzheimer's disease in the clinical point of view. We expect this new method will provide us a deeper understanding of the brain function in ways with both power spectral analysis and principle component analysis. Further studies have been conducted for more investigations.

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