Original Article

Quantitative EEG and medial temporal lobe atrophy in *Alzheimer's dementia*: Preliminary study

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Abstract

Backgrounds: The electroencephalogram (EEG) abnormalities in Alzheimer's disease (AD) have been widely reported, and medial temporal lobe atrophy (MTLA) is one of the hallmarks in early stage of AD. We aimed to assess the relationship between EEG abnormalities and MTLA and its clinical validity. **Materials and Methods:** A total of 18 patients with AD were recruited (the mean age: 77.83 years). Baseline EEGs were analyzed with quantitative spectral analysis. MTLA was assessed by a T1-axial visual rating scale (VRS). **Results:** In relative power spectrum analysis according to the right MTLA severity, the power of theta waves in C4, T4, F4, F8, and T5 increased significantly and the power of beta waves in T6, C4, T4, F8, T5, P3, T3, and F7 decreased significantly in severe atrophy group. In relative power spectrum analysis according to the left MTLA severity, the power of theta waves in T3 increased significantly and that of beta waves in P4, T6, C4, F4, F8, T5, P3, C3, T3, F3, and F7 decreased significantly in severe atrophy group. **Conclusion:** The severe MTLA group, regardless of laterality, showed more severe quantitative EEG alterations. These results suggest that quantitative EEG abnormalities are correlated with the MTLA, which may play an important role in AD process.

Key Words

Alzheimer's disease, medial temporal lobe atrophy, quantitative EEG

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Introduction

The population of patients with Alzheimer's disease (AD) has been rapidly increased as ageing has been progressing worldwide. Various clinical assessment methods have been tried to evaluate the disease severity and progression. Changes in electroencephalogram (EEG) and medial temporal lobe atrophy (MTLA) may reflect the neurophysiologic and neuropathologic alterations in AD. However, the relations between the two parameters have not been clearly investigated. The aims of this study are to elucidate the relationships between EEG and MTLA and the clinical validity in the patients with AD.

Background

Since Hans Berger, who developed the EEG, reported the pathologic EEG sequences in AD patients, a substantial number of studies using EEG in AD patients have been conducted.[1,2] It has been revealed that AD patients show increased slow waves (delta and theta) and decreased fast waves (alpha and beta) compared with normal controls.[3,4] Moreover, significant correlations between cognitive decline and EEG abnormalities were reported.[5,6]`

MTLA is regarded as a characteristic neuropathological change in the early stage of AD.[7,8] In addition, AD patients with severe MTLA on magnetic resonance imaging (MRI) showed severe memory impairment, and mild cognitive impairment patients with definite MTLA reported a higher risk of AD than patients without MTLA.[9] In brief, MTLA could be a surrogate marker of cognitive dysfunction and pathologic change in AD.

Accordingly, we planned to investigate the clinical validity of quantitative EEG and correlation with MTLA severity.

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Materials and Methods

Subjects

This study was conducted on 18 patients with AD who visited the Department of Neurology at Seoul Medical Center. Patients who met the criteria of the Neurological and Communicative Disorders and Stroke-AD and Related Disorders Association (NINCDS-ADRDA) were diagnosed with AD.[10] Cognitive functions for

analysis were assessed using the Korean Mini-Mental Status Examination (K-MMSE) and the Frontal Assessment Battery (FAB) scale.[11,12] All subjects provided written consent before the initiation of study. The study received approval by the Institutional Review Board of Seoul Medical Center.

Quantitative EEG

Digital EEG recordings (SynAmps2 Neuroscansystem, Compumedics, Charlotte, NC, USA) were performed in the resting condition (eyes closed) after regular sleep. The EEG was recorded from at 17 sites (F3, F4, F7, F8, Fz, T3, T4, T5, T6, C3, C4, Cz, P3, P4, Pz, O1, and O2) according to the international 10-20 system. The impedance of the electrode was kept below 5 kΩ at each electrode site. All EEGs were recorded with a sampling rate of 500Hz/channel and filtered using a 0.1–40 Hz bandpass filter. The recorded EEG data were analyzed in 20 epochs of 2 s without artifact or sleep waves by the neurologist. A digital fast fourier transforms (FFT)-based power spectrum analysis computed the power density of EEG with range of 1-25 Hz (1~4 Hz, 4~8 Hz, 8~12 Hz, 12~25 Hz). Absolute power is measured as EEG magnitude expressed as microvolts squared, and relative power is expressed by the power in an EEG component band, in proportion to other bands.

Brain MRI imaging and VRS

Brain imaging was performed with 1.5 Tesla MRI (SIEMENS, AvantoSyngo) on all the patients. Fast spin echo T1-weighted images with 5-mm thickness axial images parallel to the line connecting the anterior commissure (AC) and posterior commissure (PC) were obtained. The TR, TE, and flip angles were shown to be 500 ms, 11 ms, and 90°, respectively. The T1 axial imaging VRS, which has been already proven to demonstrate a high correlation with Schelten coronal VRS, was estimated as below [Table 1].[13] To sum up, in the images showing the midbrain where the hippocampus is the most clearly observed, the longest width of the hippocampus (A), the shortest distance between the hippocampus and brainstem, i.e. the width of the crural cistern and ambient cistern (C), and the width of the temporal horn of lateral ventricles (D) were assessed and scored from 0 to 4 points.[13,14]

Table 1: Axial VRS (Adapted from Kim GH *et al.*, 2009).

	A: Hippocampus	C: Cistern	D: Temporal horn
Grade 0	N	N	N
Grade 1	N	↑	N
Grade 2	↓	↑↑	↑
Grade 3	↓↓	↑↑↑	↑↑
Grade 4	↓↓↓	↑↑↑	↑↑↑

N: normal; ↑: increase; ↓: decrease VRS = Visual rating scale

Statistical analysis

Statistical analyses were conducted using the Statistical Package for the Social Sciences (SPSS) (version 11.5). The required two-tailed level of significance for all tests was set at 0.05. Data were expressed as mean ± standard deviations (SD). The means and SD of the values were calculated and submitted to statistical analysis by Fisher's exact test and the Mann–Whitney U-test.

Results

A total of 18 AD patients participated in the study (15 women and three men). Subjects' demographic characteristics are shown in Table 2. The mean age ± SD was 77.83 ± 7.96 years. The mean K-MMSE score was 17.11 ± 6.32, and the mean FAB score was 7.67 ± 3.88. Patients were divided into two groups: mild MTLA group (VRS ≤ 2) or severe MTLA group (VRS > 2). An analysis of the participants' right hemispheres showed 10 mild MTLA patients and eight severe MTLA patients, and an analysis of participants' left hemispheres showed 12 mild patients and six severe patients. In baseline characteristics analysis, no significant differences, except the apparent opposite MTLA, were found between the two groups.

In the spectral analysis of right MTLA severity, absolute theta power in the severe MTLA group increased significantly in the right parietal (P4), central (C4), temporal (T4), and frontal (F3) areas [Table 3]. Relative theta power in the severe MTLA group increased significantly in the right central (C4), temporal (T4), frontal (F4, F8) areas, and the left temporal (T5) areas. Relative beta power in the severe MTLA group decreased significantly in both hemispheric multiple areas (T6, C4, T4, F8, T5, P3, T3, and F7).

In the spectral analysis on the basis of left MTLA severity, absolute delta (P4, T6, C4, T4, P3, C3, and T3) and theta (P4, T6, C4, T4, F4, F8, O1, T5, P3, C3, T3, F3, and F5) power in the severe MTLA group increased significantly [Table 4]. In addition, relative beta power decreased significantly in multiple areas (P4, T6, C4, F4, F8, T5, P3, C3, T3, F3, and F7) and relative theta power increased significantly in the left temporal (T3) area of the severe MTLA group.

Table 2: Baseline characteristics of the subjects

Variables	Total (*N* = 18)	Right MTLA			Left MTLA		
		Mild (Rt VRS ≤ 2), n = 10	Severe (Rt VRS > 2), *n* = 8	*P*-value	Mild (Lt VRS ≤ 2), *n* = 12	Severe (Lt VRS > 2), *n* = 6	*P*-value
Sex (M:F)	3:15	1:9	2:6	0.559	1:11	2:4	0.245
Age (year)	77.83±7.96	75.4±7.76	80.88±7.59	0.122	75.58±7.91	82.33±6.44	0.083
Education (year)	4.72±4.19	4.15±3.21	5.44±5.32	0.696	4.25±3.43	5.67±5.67	0.820
K-MMSE	17.11±6.32	18.5±6.43	15.38±6.14	0.315	18±5.97	15.33±7.2	0.385
FAB	7.67±3.88	8.7±4.08	6.38±3.42	0.360	8.42±3.78	6.17±3.97	0.335
VRS (Rt)	2.06±1.16	1.2±0.79	3.13±0.35	<0.001**	1.5±1	3.17±0.41	<0.005**
VRS (Lt)	2±1.03	1.3±0.67	2.88±0.64	<0.005**	1.42±0.67	3.17±0.41	<0.001**

Values are presented as mean ± SD. *P < 0.05 **P < 0.01 SD = Standard deviation, MTLA = Medial temporal lobe atrophy, VRS = Visual rating scale, K-MMSE = Korean Mini-Mental Status Examination, FAB = Frontal assessment battery

Table 3: QEEG according to right hemispheric MTLA severity

		Absolute			Relative		
		Mild (Rt VRS ≤ 2)	Severe (Rt VRS > 2)	*P*-value	Mild (Rt VRS ≤ 2)	Severe (Rt VRS > 2)	*P*-value
O2	Delta	9.74±9.80	25.10±32.48	0.237	16.44±10.15	22.89±16.37	0.274
	Theta	9.97±10.66	13.80±7.51	0.237	16.17±12.07	19.15±12.33	0.460
	Alpha	18.16±18.55	21.05±14.39	0.274	26.13±20.29	29.85±16.69	0.573
	Beta	15.02±12.87	17.48±23.42	0.897	23.98±10.37	16.45±7.26	0.122
P4	Delta	18.76±21.89	45.75±57.90	0.083	18.99±9.03	24.84±15.28	0.762
	Theta	17.79±22.18	32.64±25.11	0.034*	16.47±11.17	22.90±8.04	0.055
	Alpha	29.48±30.97	35.94±17.49	0.122	28.30±16.71	32.67±14.37	0.237
	Beta	20.76±14.84	19.36±13.40	0.829	25.11±9.50	15.37±7.27	0.055
T6	Delta	8.61±8.17	30.84±39.62	0.122	15.67±9.02	28.83±19.56	0.173
	Theta	9.75±12.35	17.68±11.92	0.101	15.83±13.37	23.39±11.98	0.055
	Alpha	20.15±25.11	17.87±13.36	0.696	30.65±21.42	28.80±16.79	1.000
	Beta	12.66±11.0	10.70±10.58	0.237	23.82±11.62	12.91±5.76	0.034*
C4	Delta	18.97±19.61	54.45±69.75	0.173	18.94±7.94	25.79±16.93	0.829
	Theta	16.86±19.54	38.68±31.36	0.027*	15.54±9.34	23.38±6.83	0.021*
	Alpha	28.66±29.29	36.03±19.42	0.101	26.70±16.57	30.22±14.19	0.408
	Beta	21.51±10.33	21.17±13.02	0.897	26.37±9.26	16.04±8.15	0.034*
T4	Delta	14.29±15.55	44.85±60.35	0.122	23.16±14.54	33.06±19.78	0.203
	Theta	8.53±11.03	19.86±14.32	0.021*	12.44±5.84	21.59±8.60	0.012*
	Alpha	12.40±11.99	17.16±10.90	0.203	22.51±16.41	24.18±14.9	0.762
	Beta	12.02±5.58	11.79±8.98	0.460	24.80±9.14	12.87±4.82	0.009**
F4	Delta	28.83±35.40	113.94±177.51	0.146	22.67±10.93	32.81±20.71	0.408
	Theta	20.09±21.58	52.38±49.94	0.016	16.41±9.15	23.21±7.76	0.027*
	Alpha	29.75±31.76	32.24±18.22	0.146	24.36±17.32	26.07±12.59	0.408
	Beta	22.43±8.34	22.70±12.68	0.897	23.70±7.88	14.08±7.99	0.016*
F8	Delta	24.69±24.47	146.87±291.15	0.173	27.07±17.64	40.18±23.87	0.173
	Theta	12.42±15.43	33.35±30.16	0.012*	12.25±4.72	20.95±9.77	0.021*
	Alpha	19.11±21.27	22.63±11.96	0.173	21.84±17.84	21.20±11.63	0.515
	Beta	18.15±12.63	15.94±10.34	0.633	22.48±6.77	12.27±6.67	0.006**
O1	Delta	10.64±10.82	27.72±38.51	0.274	15.55±9.20	22.18±15.99	0.274
	Theta	12.33±13.57	16.59±10.61	0.237	17.00±13.20	19.20±9.94	0.237
	Alpha	21.23±24.89	23.17±15.46	0.203	26.44±18.56	30.54±17.00	0.696
	Beta	16.39±15.37	16.74±20.48	0.897	24.29±9.26	16.04±7.12	0.083
T5	Delta	12.18±14.58	66.98±131.14	0.460	17.92±7.75	28.45±22.18	0.460
	Theta	13.80±20.26	27.16±33.25	0.146	17.43±12.67	25.06±8.94	0.043*
	Alpha	15.59±18.07	18.20±12.67	0.515	24.81±11.82	29.54±15.79	0.408
	Beta	12.26±9.05	8.28±5.54	0.237	26.06±11.06	12.10±5.78	0.009**
P3	Delta	22.42±21.73	64.85±111.39	0.274	19.59±9.20	24.57±16.03	0.633
	Theta	22.95±27.29	40.26±38.71	0.122	17.37±10.91	23.64±7.96	0.068
	Alpha	30.37±32.46	40.64±25.91	0.274	25.38±13.04	31.78±13.84	0.360
	Beta	25.36±18.54	20.21±11.97	0.573	26.72±10.22	15.77±7.47	0.034*
C3	Delta	22.70±25.62	74.46±121.21	0.315	20.10±9.72	26.19±17.91	0.633
	Theta	19.07±21.59	45.08±46.00	0.101	16.54±10.69	23.00±9.06	0.068
	Alpha	30.40±30.52	38.30±22.50	0.173	26.10±16.24	30.07±14.1	0.274
	Beta	24.14±16.03	21.62±12.83	0.696	26.12±10.25	16.45±9.05	0.055
T3	Delta	17.41±20.70	96.29±168.70	0.274	23.74±10.44	36.24±24.48	0.460
	Theta	12.88±16.96	30.10±33.12	0.068	15.91±10.02	22.14±11.16	0.083
	Alpha	17.23±17.64	18.90±11.62	0.460	24.73±16.42	24.03±14.07	0.633
	Beta	11.80±6.56	9.42±4.75	0.408	22.09±8.07	12.27±8.15	0.021*
F3	Delta	31.78±41.09	131.42±205.11	0.237	24.32±11.96	32.09±21.41	0.762
	Theta	20.22±20.99	58.22±62.09	0.034*	16.64±9.67	22.66±8.52	0.083
	Alpha	31.01±31.87	39.61±21.67	0.173	25.04±17.34	27.03±13.29	0.408
	Beta	21.86±10.35	23.23±13.33	0.965	22.67±8.14	14.31±8.24	0.055
F7	Delta	23.37±22.28	123.86±191.87	0.237	27.59±12.21	40.58±24.27	0.408
	Theta	14.01±14.87	35.52±35.59	0.083	15.71±9.52	20.13±10.51	0.203
	Alpha	21.62±22.35	22.72±11.88	0.408	23.86±17.67	23.07±13.12	0.633
	Beta	14.65±6.53	12.78±6.44	0.515	20.77±7.32	12.14±7.69	0.027*

Values are presented as mean±SD. *$P < 0.05$ **$P < 0.01$ SD = Standard deviation, MTLA = Medial temporal lobe atrophy, VRS = Visual rating scale, QEEG = Quantitative electroencephalogram

Table 4: QEEG according to left hemispheric MTLA severity

		Absolute			Relative		
		Mild (Lt VRS ≤ 2)	Severe (Lt VRS > 2)	*P*-value	Mild (Lt VRS ≤ 2)	Severe (Lt VRS > 2)	*P*-value
O2	Delta	9.04±9.04	31.62±35.67	0.053	15.93±9.31	26.06±18.02	0.102
	Theta	9.23±9.81	16.55±6.49	0.083	15.87±11.10	20.75±13.88	0.385
	Alpha	18.14±16.92	22.05±16.58	0.437	29.07±19.76	25.2±16.52	0.682
	Beta	13.83±11.98	20.68±26.79	0.964	23.21±9.56	15.47±8.32	0.151
P4	Delta	16.97±20.24	58.32±62.73	0.007**	18.02±8.50	28.73±15.91	0.213
	Theta	16.82±20.25	39.53±25.50	0.013*	17.01±10.52	23.96±8.34	0.083
	Alpha	29.00±28.08.	39.05±19.40	0.151	30.83±16.39	29.07±14.68	0.892
	Beta	19.31±13.85	21.8±14.92	0.892	24.22±8.85	13.91±7.97	0.041*
T6	Delta	7.86±7.60	39.75±42.62	0.007**	15.45±8.30	33.66±20.48	0.053
	Theta	9.17±11.32	21.49±11.23	0.024*	16.42±12.19	24.73±13.82	0.125
	Alpha	19.27±23.00	18.87±15.02	0.682	33.14±20.34	23.20±15.33	0.335
	Beta	11.29±10.46	12.78±11.64	0.820	22.38±11.09	12.17±6.43	0.041*
C4	Delta	17.26±18.18	69.71±75.46	0.013*	18.35±7.44	29.25±18.42	0.437
	Theta	16.22±17.88	47.22±31.87	0.010*	16.49±8.95	24.10±7.37	0.053
	Alpha	27.47±26.64	40.87±20.39	0.125	28.55±15.86	27.68±15.26	0.892
	Beta	20.09±10.24	23.90±13.67	0.616	25.43±9.02	14.47±8.18	0.032*
T4	Delta	12.93±14.43	57.75±65.57	0.013*	22.80±13.26	37.08±21.55	0.180
	Theta	8.39±10.11	23.91±14.24	0.007**	14.26±6.92	20.99±9.90	0.180
	Alpha	12.32±11.08	18.90±11.85	0.180	24.92±15.92	19.91±14.85	0.494
	Beta	10.66±5.98	14.41±8.88	0.616	22.76±9.55	12.97±5.70	0.053
F4	Delta	26.92±32.45	146.13±197.80	0.053	23.39±11.33	34.77±22.82	0.385
	Theta	19.23±19.64	64.71±52.42	0.013*	17.34±8.55	23.62±9.13	0.125
	Alpha	28.18±29.02	42.88±17.44	0.083	25.23±15.86	24.92±14.53	0.750
	Beta	20.69±8.99	26.28±12.16	0.494	22.55±8.25	13.17±7.96	0.032*
F8	Delta	23.05±22.55	190.89±330.71	0.067	28.17±17.18	42.34±26.46	0.213
	Theta	12.05±14.01	41.07±31.41	0.007**	13.87±5.78	20.60±11.47	0.213
	Alpha	18.09±19.47	25.84±11.96	0.083	22.80±16.55	19.07±12.22	1.000
	Beta	16.11±12.43	19.29±9.65	0.437	20.80±7.54	12.23±7.33	0.041*
O1	Delta	9.72±10.08	35.25±42.44	0.053	14.88±8.53	25.73±17.17	0.053
	Theta	11.10±12.61	20.47±9.23	0.041*	16.37±12.13	21.20±10.67	0.125
	Alpha	21.03±22.84	24.21±17.24	0.291	29.77±18.65	25.24±16.07	0.553
	Beta	14.92±14.36	19.80±23.25	0.682	23.34±8.68	15.19±8.18	0.083
T5	Delta	10.71±13.65	88.20±148.04	0.067	17.17±7.51	33.46±23.64	0.125
	Theta	12.15±18.73	34.91±35.49	0.010*	17.55±11.58	27.37±8.95	0.013*
	Alpha	14.64±16.54	20.96±13.59	0.291	27.84±12.84	25.06±15.85	0.750
	Beta	10.91±8.78	9.66±5.80	0.892	24.81±10.45	9.96±4.89	0.005**
P3	Delta	19.89±20.55	84.06±124.89	0.024*	18.57±8.87	28.26±16.91	0.291
	Theta	20.93±25.18	50.05±40.39	0.024*	17.86±10.38	24.74±7.92	0.067
	Alpha	28.66±29.66	47.50±26.65	0.125	27.40±12.97	29.87±15.34	0.750
	Beta	23.28±17.48	22.64±13.06	0.964	26.29±9.43	12.98±5.95	0.010*
C3	Delta	20.25±23.90	96.62±134.95	0.024*	19.34±9.27	29.75±19.39	0.291
	Theta	17.56±19.87	56.76±48.02	0.018*	16.94±9.80	24.36±10.12	0.102
	Alpha	28.46±27.98	44.81±22.46	0.151	27.74±15.32	28.11±15.88	0.682
	Beta	22.22±15.31	24.64±13.36	0.682	25.68±9.85	14.10±8.14	0.032*
T3	Delta	15.47±19.28	126.47±188.33	0.013*	23.05±10.14	41.79±25.82	0.151
	Theta	11.55±15.66	38.50±34.60	0.007**	15.95±9.09	24.14±12.42	0.067
	Alpha	15.97±16.22	21.98±11.98	0.250	25.98±15.16	21.29±15.48	0.750
	Beta	10.89±6.36	10.43±4.98	1.000	21.87±7.71	9.44±6.44	0.005**
F3	Delta	29.11±37.85	169.97±227.46	0.053	24.54±12.40	34.22±23.22	0.682
	Theta	18.81±19.27	73.69±65.17	0.007**	17.01±8.81	23.94±9.63	0.083
	Alpha	29.07±29.20	46.35±20.89	0.067	26.03±15.91	25.72±15.34	0.750
	Beta	20.23±10.37	26.94±13.06	0.437	22.07±8.28	12.72±7.47	0.041*
F7	Delta	21.87±20.83	160.36±31.62	0.083	28.41±13.41	43.29±25.88	0.385
	Theta	12.75±13.77	45.21±36.36	0.010*	15.81±8.71	21.41±11.96	0.213
	Alpha	20.00±20.57	26.32±11.63	0.180	24.93±16.40	20.67±14.04	0.892
	Beta	13.21±6.82	15.03±5.72	0.553	19.95±7.44	10.90±7.64	0.032*

Values are presented as mean±SD. *$P < 0.05$ **$P < 0.01$ SD = Standard deviation, MTLA = Medial temporal lobe atrophy, VRS = Visual rating scale, QEEG = Quantitative electroencephalogram

Discussion

We confirmed that the severe MTLA group showed more severe quantitative EEG abnormalities in multiple areas than the mild MTLA group in this study. However, laterality in quantitative EEG abnormalities could not be clearly distinguished because most patients who showed severe unilateral MTLA also showed severe MTLA on the opposite side as well. Further research could clarify this issue by testing AD patients with asymmetric MTLA.

Despite the insufficient amount of information on detailed spatial distribution, the correlation between quantitative EEG abnormalities and MTLA was reported previously.[15] Our study revealed that the severe MTLA group showed more severe quantitative EEG abnormality than mild MTLA group in most of cerebral areas except for occipital areas regardless of atrophic side. Considering that MTLA appears as constructional changes, after pathophysiological changes such as beta amyloid deposition or tau hyperphosphorylation, the presence of electrophysiological changes of the brain in severe MTLA group might have preceded the atrophy, which could be reflected in quantitative EEG. Greater cortical atrophy in patients with mild AD than in patients with amnestic mild cognitive impairment (MCI) was seen in most of brain cortical areas.[16] The differences are greater in medial and inferior temporal, posterior cingulate, temporal, and parietal association corticies, which are affected earlier in the disease process. Our finding that the severe MTLA group showed more severe abnormal quantitative EEG findings in nearly the entire brain is in line with the previous report.[16] The quantitative EEG showed more prominent degradation in the severe MTLA group than in the mild MTLA group, especially in the left hemisphere. Therefore, quantitative EEG assessing MTLA could be a useful strategy in observing the progress of AD.

The present study has several limitations, such as small number of subjects, resulting in low statistical power, and no significant differences of MMSE and FAB scores between the severe and mild MTLA groups. Considering the previous studies reporting the correlation between cortical atrophy and cognition, however, cortical atrophy, quantitative EEG, and cognition may be closely related and future research could determine this with a large sample.[17] Because relation between beta amyloid load and cerebral atrophy has not been established in AD patients, degree of pathological change from quantitative EEG could not be inferred.[18] Contrary to MCI or AD, patients with subjective cognitive impairment showed a significant relationship between beta amyloid deposition and global/gray matter atrophy, which suggests that beta amyloid plays a major role in the very early stage, and other pathologic events may affect the subsequent atrophy process. Further study clarifying the usefulness of quantitative EEG as a neurophysiologic tool reflecting AD progress is needed.

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