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Abstract: Purpose: To investigate whether serial electroencephalographic (EEG) findings can predict relapse of epileptic spasms after synthetic adrenocorticotropic hormone (ACTH) therapy in patients with West syndrome (WS). Subjects and methods: Thirty-nine WS patients (8 cryptogenic and 31 symptomatic) were included in this study. These patients received ACTH therapy for the first time and were regularly followed up for more than three years at our hospital. Sixteen patients (41.0%) showed seizure relapse (relapse group) and 23 patients (59.0%) did not show relapse (non-relapse group). We used survival analysis to investigate the influence of etiology and presence of epileptic discharges after the ACTH therapy on seizure outcome. Results: Immediately after the ACTH therapy, etiology was associated with seizure outcome ($p = 0.003$). In the early stage (1 month after the ACTH therapy), only the presence of epileptic discharges ($p = 0.001$) had a significant association with seizure outcome, regardless of etiology. Because all relapsed patients were in the symptomatic group, we performed the same statistical analysis on symptomatic WS patient data only. We found that the group with no epileptic discharges on EEG showed a significantly higher seizure-free rate than those with epileptic discharges in the early stage ($p = 0.0091$). Conclusion: This study demonstrated that serial EEG findings after ACTH therapy are significantly related to relapse of epileptic spasms.

Suggested Reviewers:

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Predictive factors for relapse of epileptic spasms after adrenocorticotropic hormone therapy in West syndrome

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1. Introduction

West syndrome (WS) is an age-dependent epileptic encephalopathy that causes psychomotor deterioration even in normally-developed infants. Mental outcome is particularly poor in patients whose epileptic spasms (infantile spasms) cannot be controlled by treatment. Adrenocorticotropic hormone (ACTH) therapy is considered the most effective therapy for WS, and its initial effect is reported to be excellent [1-13]. However, nearly one-half of patients whose spasms were once suppressed experience relapse [1,5,14-16]. Despite the fact that relapse after ACTH therapy is such a relevant issue, the factors related to relapse and its prevention have not yet been fully investigated. Because electroencephalography (EEG) precisely reflects epileptic brain dysfunction in WS patients, we suggest that it could be a powerful tool for treatment of patients with WS. Although there are several studies on EEG changes during and after ACTH therapy [17,18,19], there are few detailed studies on the relationship between EEG features after ACTH therapy and relapse of epileptic spasms.

In this study, we investigated predictive factors for relapse of epileptic spasms after ACTH therapy in patients with WS, focusing especially on the issue of whether serial EEG findings can predict relapse.

1. Subjects and methods

1.1. Patients and ACTH therapy protocol

Sixty-six WS patients were admitted to the Department of Child Neurology in Okayama University Hospital between January 2000 and August 2010 and received synthetic ACTH therapy. All patients had spasms and hypsarrhythmia on EEG. Among these patients, those who fulfilled all of the following criteria were

included in this study: 1) received their first ACTH therapy; 2) showed spasm cessation and hypsarrhythmic EEG pattern disappearance upon completion of ACTH therapy; 3) completed ACTH therapy according to the Okayama University Hospital protocol; and 4) were regularly followed-up after completion of ACTH therapy with detailed clinical observation and EEGs for more than three years. According to the International Classification of Epilepsies and Epileptic Syndromes (ILAE, 1989), patients with underlying known etiology or previous signs of brain damage (psychomotor retardation, neurological signs, radiological signs or other types of seizures besides spasms) were categorized into the symptomatic group. The cryptogenic group was characterized by a lack of previous signs of brain damage and known etiology [20].

According to the Okayama University Hospital ACTH therapy protocol, synthetic ACTH was administered intramuscularly once daily at a dose of 0.005 to 0.015 mg (0.2-0.6 IU)/kg/day for 14 consecutive days. If spasms or epileptic discharges on EEG remained, the same or an increased ACTH dose (0.005-0.025 mg/kg/day) was continued, and ACTH therapy was stopped when the effect of ACTH for each patient reached a plateau. ACTH was administered for up to 35 days.

1.2. EEG and etiology analysis

After completing ACTH therapy, all patients underwent repeated EEG recordings every two to four weeks. These serial EEGs were classified into five stages according to the timing after the end of ACTH therapy: immediate stage (immediately after); very early stage (2 weeks after); early stage (1 month after); and middle stage (3 months after). We selected and analyzed EEGs that were recorded on the day nearest to the timing of each stage. We also defined late stage EEG as the first EEG recorded after four months for each

patient. EEGs were recorded for more than 40 min, while the patient was both asleep and awake, using a Nihon Kohden Neurofax or NEC SINAFIT 1000.

Two pediatric neurologists (Y.H. and H.Y.) independently evaluated the EEGs. If there was any disagreement regarding EEG findings, including the definition of hypsarrhythmia, a final decision was reached through advice given by a third pediatric neurologist (Y.O.) who was blinded to information related to the patients' clinical background. We used survival analysis to investigate the influence of etiology (cryptogenic or symptomatic) and the presence of epileptic discharges after completion of ACTH therapy on seizure outcome. Kaplan-Meier analysis, the log-rank test and the Cox proportional hazards model were used for statistical analysis. Differences were considered to be significant with p values less than 0.05.

We also analyzed the changing course of epileptic discharges over time in the group of patients with no relapse of spasms (non-relapse group) and the group of patients with relapse of spasms (relapse group). This analysis focused on how spikes developed into hypsarrhythmia in the relapse group after completion of ACTH.

1.3. Medical treatment after completion of ACTH therapy

If an antiepileptic drug (AED) was partially effective before ACTH therapy or if it was continuously administered during ACTH therapy, the same AED was generally used after ACTH therapy. Otherwise, we chose valproic acid (VPA), which was reported to show relatively high efficacy [13,21,22] and rapid appearance of effect, to allow efficacy to be determined in a short period of time. VPA was administered to 27 patients, zonisamide to 13 patients, clonazepam to 10 patients and other AEDs to 7 patients. All patients

were hospitalized until at least two weeks after completion of ACTH therapy, and they were treated as outpatients every two to four weeks after discharge.

2. Results

2.1. Patient characteristics

Of the 66 patients with WS who were treated at our hospital, 39 patients (24 boys and 15 girls) were analyzed in this study. The remaining 27 patients were excluded for the following reasons: 6 patients were receiving ACTH therapy for the second time; 1 patient received steroid pulse therapy for a lung disease before ACTH therapy; 12 patients showed no suppression of spasms by ACTH therapy; 6 patients had ACTH therapy discontinued because of worsening spasms and/or EEG findings or infection; and 2 patients were lost to follow-up. Eight patients (20.5%) were classified as having cryptogenic WS and 31 patients (79.5%) were classified as having symptomatic WS. The total duration of ACTH therapy ranged from 11 to 37 days (mean: 23.5 days). Additional ACTH therapy was performed in 38 out of the 39 patients. Ten patients (5 in the non-relapse group and 5 in the relapse group) received additional therapy because of the persistence of epileptic spasms, and 28 patients (17 in the non-relapse group and 11 in the relapse group) received additional therapy because of spikes on EEG at 14 days after the start of ACTH therapy. The age at onset of spasms ranged from 2 to 15 months (mean: 6.7 months). The follow-up period ranged from 3 years, 0 months to 12 years, 9 months (mean: 7 years, 5 months). Sixteen patients (41.0%) had seizure relapse after ACTH therapy (relapse group) with epileptic spasms, and all of them belonged to the symptomatic group. No relapse was observed in 23 patients (59.0%) (non-relapse group: 15 symptomatic and 8 cryptogenic

patients). Table 1 shows the characteristics of symptomatic patients. In patients with symptomatic WS, the etiology was not different between the non-relapse and the relapse groups (Table 1). The length of time from the end of ACTH therapy to seizure relapse was 5 days to 25 months (mean: 6.6 months). Only three patients relapsed between five days and one month after completion of ACTH therapy, and the remaining patients relapsed at two months or thereafter.

2.2. Association between EEG findings and relapse

EEGs in the immediate stage were recorded on - 0.18 ± 1.10 days (mean ± standard deviation [SD]), those in the very early stage on 12.18 ± 2.27 days, those in the early stage on 30.64 ± 5.97 days and those in the middle stage on 90.64 ± 14.02 days. The late-stage EEGs were recorded on 146.51 ± 19.06 days.

We compared EEG findings between the relapse and the non-relapse groups at each stage after completion of ACTH therapy (Figure 1). In the immediate stage, the existence rate of epileptic discharges did not differ between the non-relapse group and the relapse group. In the very early stage, spikes were observed in 16 patients (69.6%; 5 cryptogenic patients and 11 symptomatic patients) in the non-relapse group, and in 16 patients (100%) in the relapse group. After the reappearance of spikes on EEG in the very early stage, epileptic discharges did not disappear in any patient in the relapse group until the seizures returned. However, in all patients except for one symptomatic patient in the non-relapse group, the epileptic discharges disappeared at least once by the middle stage. The appearance rate of epileptic discharges decreased gradually towards the middle stage in the non-relapse group.

The locations of epileptic discharges in the immediate stage did not differ between the non-relapse and

relapse groups. In the non-relapse group, the number of patients with multifocal spikes decreased along with the decrease in the number of patients with spikes until the middle stage. In the relapse group, “multifocal” cases (including hypsarrhythmia) subsequently increased, and all patients showed “occipital” or “multifocal” spikes after the middle stage. Hypsarrhythmia reappeared in the early stage in one patient, in the middle stage in three patients and in the late stage in six patients. Seven patients developed spasms without recurrence of hypsarrhythmia on EEG (Table 1). Representative EEG changes in one patient each in the relapse and non-relapse groups are shown in Figure 2.

2.3. Association of relapse with EEG findings and etiology

Figure 3 shows Kaplan-Meier curves of the seizure-free rate over time in the group with no epileptic discharges and in that with epileptic discharges on EEG performed in the immediate, very early and early stages. Most relapses occurred in the middle stage and thereafter. Therefore, we chose EEGs in the above-mentioned three stages for relapse prediction analysis. Overall, the group with no epileptic discharges on EEG in the very early stage ($p = 0.04$) and the early stage ($p < 0.001$) showed a significantly higher seizure-free rate, whereas there was no significant difference in the seizure-free rate between the two groups in the immediate stage ($p = 0.3326$).

Because all relapsed patients were in the symptomatic group, we performed statistical analysis on data from symptomatic patients only to avoid any selection bias. Patients without epileptic discharges on EEG in the early stage showed a significantly higher seizure-free rate than those with epileptic discharges ($p = 0.0091$). Also, patients without epileptic discharges in the very early stage showed a lower seizure relapse

rate than those with epileptic discharges on EEG in that stage, though it did not reach the statistical significance ($p = 0.0729$). In contrast, there was no significant difference in the seizure-free rate between the patients with epileptic discharges and those without epileptic discharges on EEG in the immediate stage ($p = 0.8162$; Figure 4).

We also performed multivariate analysis using the Cox proportional hazards model, and included etiology as a covariable in addition to epileptic discharges. In the immediate stage, the presence of epileptic discharges on EEG had no influence on the seizure-free rate; however, etiology had an influence ($p = 0.003$), with symptomatic patients having a lower seizure-free rate than cryptogenic patients. In the very early stage, the presence of epileptic discharges ($p = 0.02$) and etiology ($p = 0.009$) significantly affected the seizure-free rate. Patients with epileptic discharges and those with symptomatic etiology had a lower seizure-free rate. In contrast, in the early stage, only the presence of epileptic discharges was associated with seizure relapse ($p = 0.001$), regardless of etiology.

3. Discussion

Regarding the relapse of spasms after ACTH therapy, Ohtsuka et al. reported that seizures relapsed in 10% of cryptogenic WS patients and in 49.3% of symptomatic WS patients in long-term follow-up [1]. Other investigators also reported that 14.3 to 46.2% of cryptogenic WS patients and 21.7 to 47.4% of symptomatic WS patients had seizure relapse after initial therapy, including ACTH therapy [5,14-16,23,24]. In the present study, there was no seizure recurrence in the cryptogenic patients and in 51.6% of the symptomatic patients. Although relapse after ACTH therapy is both a relevant and important issue, there are few detailed studies

on the relationship between seizure relapse and EEG findings in patients with WS. This might be because the usefulness of a detailed analysis of follow-up EEGs after completion of ACTH therapy has not been widely recognized.

Itomi et al. concluded that the existence of focal EEG abnormalities (spikes, sharp waves and high-voltage slow waves) was not related to the seizure outcome three months after starting the initial therapy [3], suggesting that EEG abnormalities are not useful in predicting seizure outcome after various therapies, including ACTH. However, after reviewing their data thoroughly, we found that all patients whose EEG abnormalities resolved by three months after treatment had no recurrence of spasms before the end of follow-up. Recently, Yamada et al. concluded that disappearance of epileptic activity might be associated with a sustained response without relapse after initial treatment (high-dose vitamin B6, zonisamide, sodium valproate and ACTH) [19]. Gaily et al. reported that persistent multifocal spikes were always associated with continuing spasms after vigabatrin therapy [4]. Koo et al. reported that persistence of hypsarrhythmia or failure of EEG normalization for two weeks or more after initiation of ACTH therapy correlated with poor cognitive outcome [5].

The present study is the first to statistically indicate that the appearance of epileptic discharges after completion of ACTH therapy was related to seizure outcome. Overall, including both cryptogenic and symptomatic patients, the group with no epileptic discharges on EEG at approximately two weeks and at one month after the end of ACTH therapy showed a significantly higher seizure-free rate. Results of the second analysis, which excluded the cryptogenic patients, were almost the same: the group with no epileptic discharges on EEG at approximately one month after completion of ACTH therapy showed a significantly

higher seizure-free rate.

In our study, the time to relapse after completion of ACTH therapy ranged from 5 days to 25 months (mean: 6.6 months). Riikonen reported that seizure relapse occurred a few days to 18 months (mean: 4.6 months) after completion of ACTH therapy [17], and Lin et al. reported that relapse occurred 4.6 ± 1.8 months after completion of ACTH therapy [6]. Our data were compatible with those of these previous studies and most patients relapsed two months or later after completion of ACTH therapy. Therefore, the presence of epileptic discharges, especially multifocal spikes before two months, can be used as a warning sign of imminent relapse. In addition, our study indicated that once epileptic discharges disappeared during this period, the possibility of spasm relapse would be reduced even though epileptic discharges later reappeared.

Multivariate analysis on the entire study population showed that etiology was another significant predictive factor for relapse. It was the only significant predictive factor for relapse immediately after ACTH therapy. At approximately two weeks after completion of ACTH therapy, the presence of epileptic discharges on EEG also becomes a significant predictive factor, together with etiology. At one month after completion of ACTH therapy, the presence of epileptic discharges becomes the only significant predictive factor. These findings suggest that both cerebral dysfunction caused by organic brain damage and epileptogenesis expressed as epileptic discharges are complicatedly associated with seizure relapse after ACTH therapy. The results of the present study indicate that detailed EEG investigation after ACTH therapy, particularly in symptomatic patients, can be a useful tool for predicting seizure relapse.

The universal guidelines for treatment after ACTH therapy have not yet been established. In our

hospital, we perform AED treatment after ACTH therapy for all patients, although AED treatment after ACTH therapy varies from place to place, including no AED treatment for patients without clinical seizures and prolonged intermittent use of ACTH for patients who experience relapse [25]. Once WS occurs or relapses, the efficacy of conventional AEDs decreases [27-29]. Yoshinaga et al. proposed early AED intervention before the onset of WS for high-risk patients based on the experience of successfully treating some patients [26]. Early intervention or enhancement of AED treatments using EEGs after ACTH therapy might also be promising to prevent relapse of spasms. Although, we usually use VPA after ACTH therapy because of its high and rapid efficacy [16,26], other AEDs, such as zonisamide, topiramate, lamotrigine and levetiracetam, might be more beneficial [11,23,30]. EEG-based intensive AED treatment to prevent relapse of spasms after ACTH therapy should be administered for a maximum of approximately 2 years to avoid unnecessary long-term treatment, because relapse of spasms occurred by 25 months after completion of ACTH therapy in the present study.

A limitation of this study is that it was not strictly designed prospective study. Despite this limitation, we obtained some significant findings. Larger-scale prospective studies are needed to confirm these results as well as the significance of prophylactic therapy to prevent relapse of spasms after ACTH therapy.

In conclusion, we recommend regular follow-up examinations for the first two months after completion of ACTH therapy, including detailed EEGs, in WS patients especially symptomatic patients. During this time, the persistence or worsening of epileptic discharges on EEG, especially multifocal epileptic discharges, is highly predictive for imminent relapse of spasms.

Disclosures or conflict of interest

None of the authors has any conflict of interest to disclose.

References

[1] Ohtsuka Y, Murashima I, Oka E, Ohtahara S. Treatment and prognosis of West syndrome. J Epilepsy 1994;7:279-84.

[2] Nitsche V, Mascher H. The pharmacokinetics of valproic acid after oral and parenteral administration in healthy volunteers. Epilepsia 1982;23:153-62.

[3] Itomi K, Okumura A, Negoro T, Watanabe K, Natsume J, Takada H, et al. Prognostic value of positron emission tomography in cryptogenic West syndrome. Dev Med Child Neurol 2002;44:107-11.

[4] Gaily E, Liukkonen E, Paetau R, Rekola M, Granström ML. Infantile spasms: diagnosis and assessment of treatment response by video-EEG. Dev Med Child Neurol 2001;43:658-67.

[5] Koo B, Hwang PA, Logan WJ. Infantile spasms: outcome and prognostic factors of cryptogenic and symptomatic groups. Neurology 1993;43:2322-7.

[6] Lin HC, Young C, Wang PJ, Lee WT, Shen YZ. ACTH therapy for Taiwanese children with West syndrome-efficacy and impact on long-term prognosis. Brain Dev 2006;28:196-201.

[7] Suzuki M, Okumura A, Watanabe K, Negoro T, Hayakawa F, Kato T, et al. The predictive value of electroencephalogram during early infancy for later development of West syndrome in infants with cystic periventricular leukomalacia. Epilepsia 2003;44:443-6.

[8] Cusmai R, Ricci S, Pinard JM, Plouin P, Fariello G, Dulac O. West syndrome due to perinatal insults.

Epilepsia 1993;34:738-42.

[9] Ohtsuka Y, Murashima I, Asano T, Oka E, Ohtahara S. Partial seizures in West syndrome. Epilepsia 1996;37:1060-7.

[10] Riikonen R. Recent advances in the pharmacotherapy of infantile spasms. CNS Drugs 2014;28:279-90.

[11] Go CY, Mackay MT, Weiss SK, Stephens D, Adams-Webber T, Ashwal S, et al. Evidence-based guideline update: Medical treatment of infantile spasms. Neurology 2012;78:1974-80.

[12] Pellock JM, Hrachovy R, Shinnar S, Baram TZ, Bettis D, Dlugos DJ, et al. Infantile spasms: A U.S. consensus report. Epilepsia 2010;51:2175-89.

[13] Hancock EC, Osborne JP, Edwards SW. Treatment of infantile spasms. Cochrane Database Syst Rev 2013;6:1-69.

[14] Kondo Y, Okumura A, Watanabe K, Negoro T, Kato T, Kubota T, et al. Comparison of two low dose ACTH therapies for West syndrome: their efficacy and side effect. Brain Dev 2005;27:326-30.

[15] Cohen-Sadan S, Kramer U, Ben-Zeev B, Lahat E, Sahar E, Nevo Y, et al. Multicenter long-term follow-up of children with idiopathic West syndrome: ACTH versus vigabatrin. Eur J Neurol 2009;16:482-7.

[16] Yanagaki S, Oguni H, Hayashi K, Imai K, Funatuka M, Tanaka T, et al. A comparative study of high-dose and low-dose ACTH therapy for West syndrome. Brain Dev 1999;21:461-7.

[17] Riikonen R. A long-term follow-up study of 214 children with the syndrome of infantile spasms. Neuropediatrics 1982;13:14-23.

[18] Riikonen R. Long-term outcome of West syndrome: a study of adults with a history of infantile spasms. Epilepsia 1996;37:367-72.

[19] Yamada K, Toribe Y, Kimizu T, Kimura S, Ikeda T, Mogami Y, et al. Predictive value of EEG findings at control of epileptic spasms for seizure relapse in patients with West syndrome. Seizure 2014;23:703-7.

[20] Commission on classification and terminology of the International League Against Epilepsy, proposal for revised classification of epilepsies and epileptic syndromes. Epilepsia 1989;30:389-99.

[21] Ohtsuka Y, Amano R, Mizukawa M, Oka E, Ohtahara S. Treatment of intractable childhood epilepsy with high-dose valproate. Epilepsia 1992;33:158-64.

[22] Ito M. Antiepileptic drug treatment of West syndrome. Epilepsia 1998; 39 Suppl 5:38-41.

[23] Lagae L, Verhelst H, Ceulemans B, Meirleir LD, Nassogne MC, Borchgrave VD, et al. Treatment and long term outcome in West syndrome: the clinical reality. A multicentre follow up study. Seizure 2010;19:159-64.

[24] Mohamed BP, Scott RC, Desai N, Gutta P, Patil S. Seizure outcome in infantile spasms-a retrospective study. Epilepsia 2011;52:746-52.

[25] Okanishi T, Sugiura C, Saito Y, Maegaki Y, Ohno K, Togari H. Long-term weekly ACTH therapy for relapsed West syndrome. Pediatr Neurol 2008;38:445-9.

[26] Yoshinaga H, Endoh F, Kikumoto K, Inoue T, Oka M, Ohtsuka Y. Epilepsy development in infancy with epileptic discharges. Brain Dev 2007;29:217-23.

[27] Siemes H, Spohr HL, Michael T, Nau H. Therapy of infantile spasms with valproate: results of a prospective study. Epilepsia 1988;29:553-60.

[28] Suzuki Y. Zonisamide in West syndrome. Brain Dev 2001;23:658-61.

[29] Yanai S, Hanai T, Narazaki O. Treatment of infantile spasms with zonisamide. Brain Dev

1999;21:157-61.

[30] Tsao CY. Current trends in the treatment of infantile spasms. Neuropsychiatr Dis Treat. 2009;5:289-99.

Table(s)

Table 1. The clinical profile and course of symptomatic cases

Case No.	Etiology	Time to seizure relapse after completion of ACTH therapy	Time to reappearance of hypsarrhythmia after completion of ACTH therapy	Time of seizure suppression before relapse
9	PI, HIE	N/A	N/A	N/A
10	BM	N/A	N/A	N/A
11	Unknown	N/A	N/A	N/A
12	PI, IH	N/A	N/A	N/A
13	Chromosomal anomalies	N/A	N/A	N/A
14	PI	N/A	N/A	N/A
15	PI, MC	N/A	N/A	N/A
16	PI, IH, MC	N/A	N/A	N/A
17	PI, IH, PVL	N/A	N/A	N/A
18	PI	N/A	N/A	N/A
19	PI, PVL	N/A	N/A	N/A
20	Hypomelanosis of Ito	N/A	N/A	N/A
21	Fetal-maternal transfusion	N/A	N/A	N/A
	syndrome	N/A	N/A	N/A
22	Unknown	N/A	N/A	N/A
23	Unknown			
24	Unknown	5 days	5 M	14 days
25	Unknown	8 days	N/A (only multifocal spikes)	17 days
26	Unknown	1 M	4 M	1 M
27	BM	2 M	N/A (only multifocal spikes)	2 M
28	PI, MC, PVL	2 M	2 M	2 M
29	HIE	2 M	3 M	3 M
30	Unknown	3 M	4 M	4 M
31	TS	3 M	N/A (only multifocal spikes)	3 M
32	Unknown	3 M	7 M	4 M
33	Unknown	6 M	N/A (only multifocal spikes)	7 M
34	PI	8 M	1 M	9 M
35	PI	9 M	8 M	9 M
36	Unknown	12 M	N/A (only multifocal spikes)	13 M
37	HIE, PVL	13 M	N/A (only multifocal spikes)	13 M
38	BM	16 M	19 M	17 M
39	PI	25 M	N/A (only multifocal spikes)	25 M

BM, brain malformation; IH, intracranial hemorrhage; PI, premature infant; MC, multiple conception; HIE, hypoxic-ischemic encephalopathy; TS, tuberous sclerosis; M, month(s); N/A, not applicable

No. 9-23 are in the non-relapse group; No. 24-39 are in the relapse group

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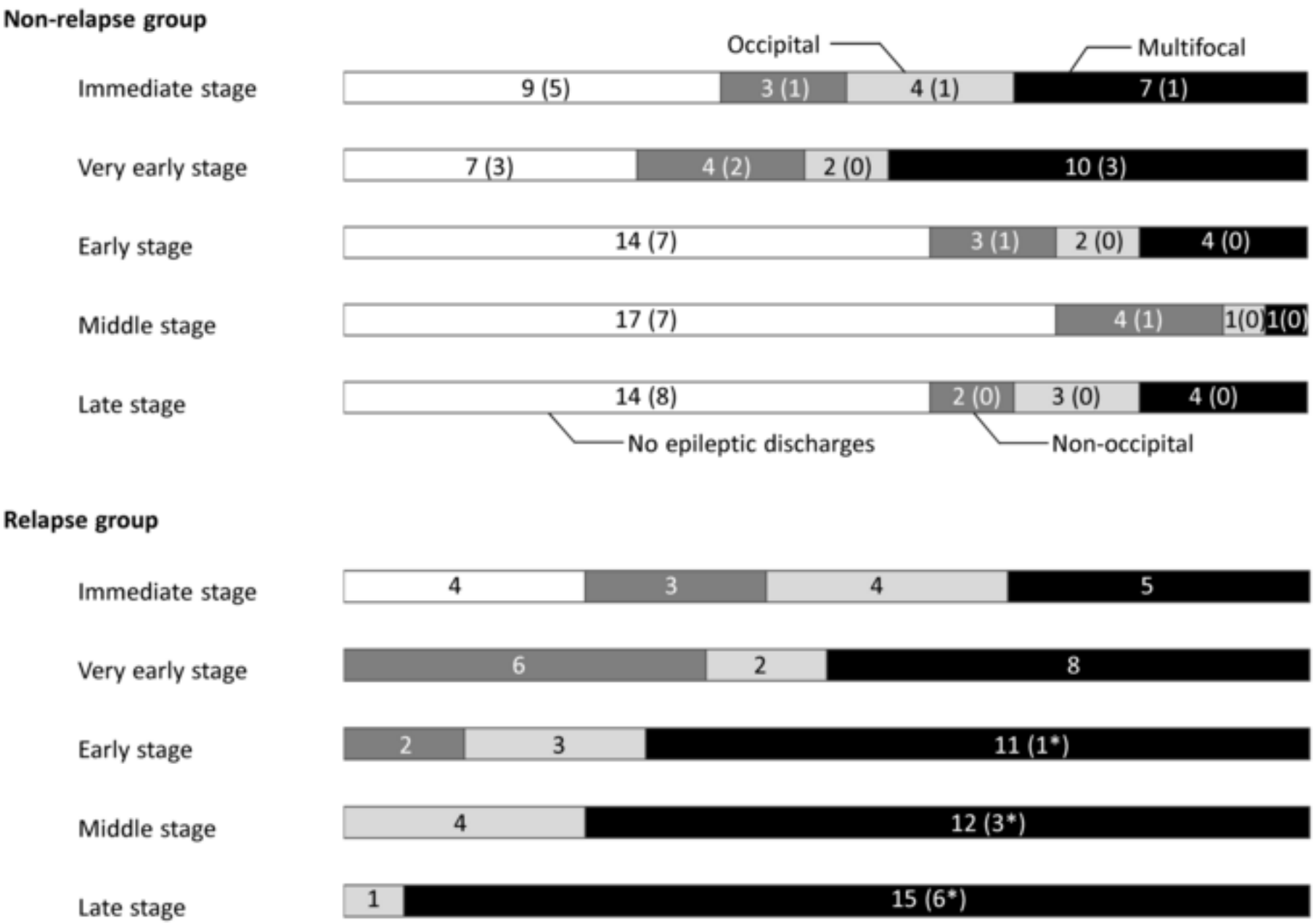

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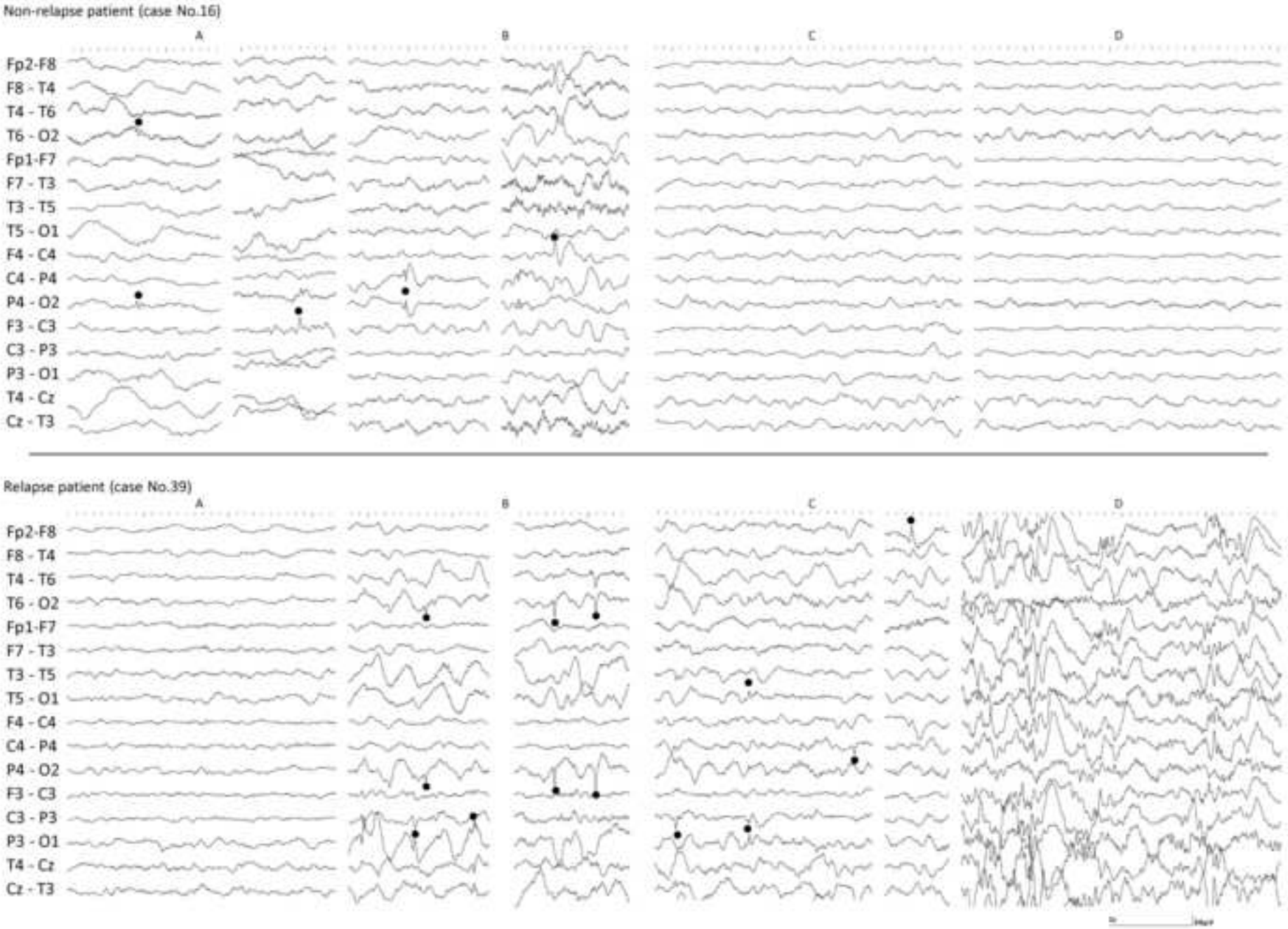

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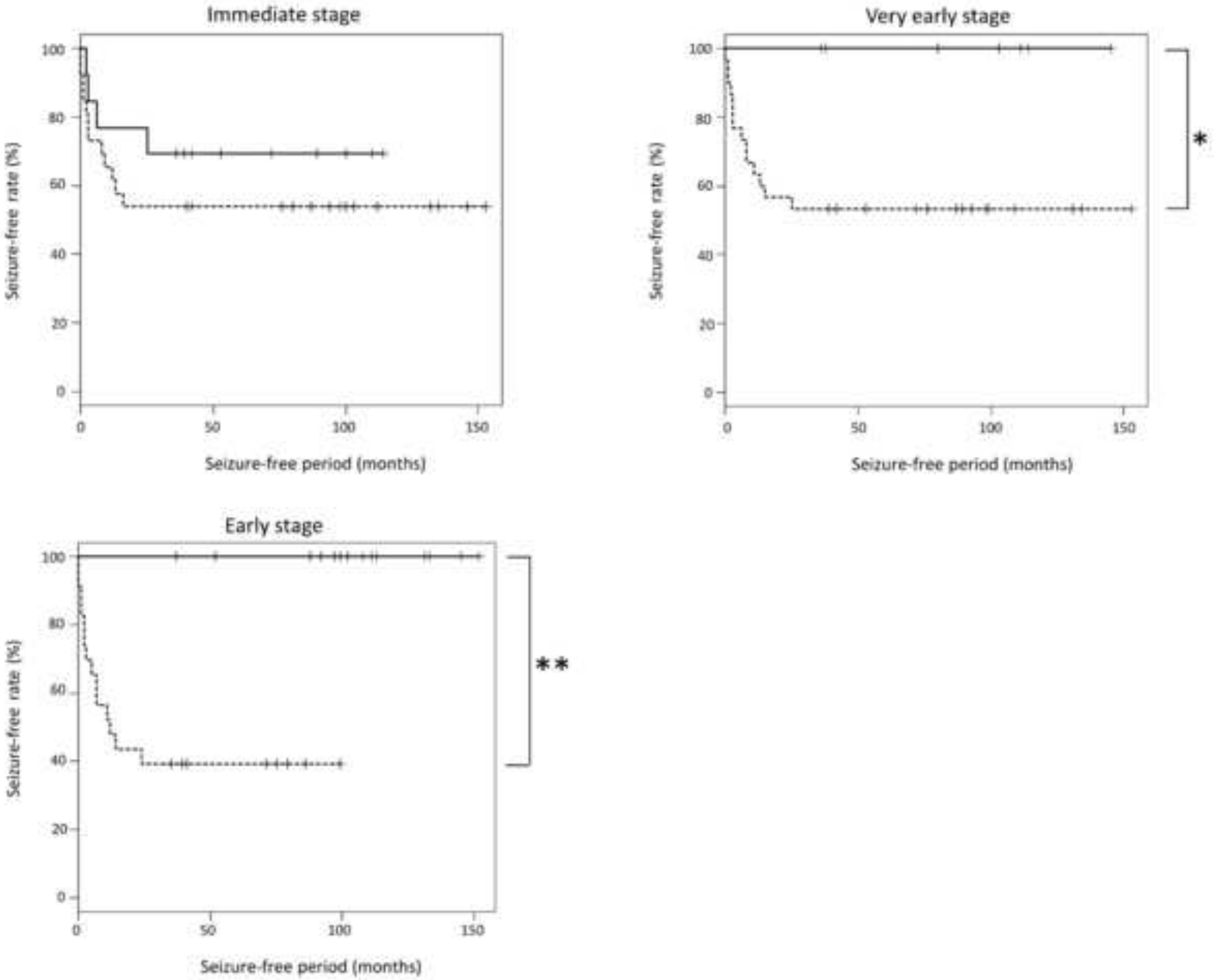

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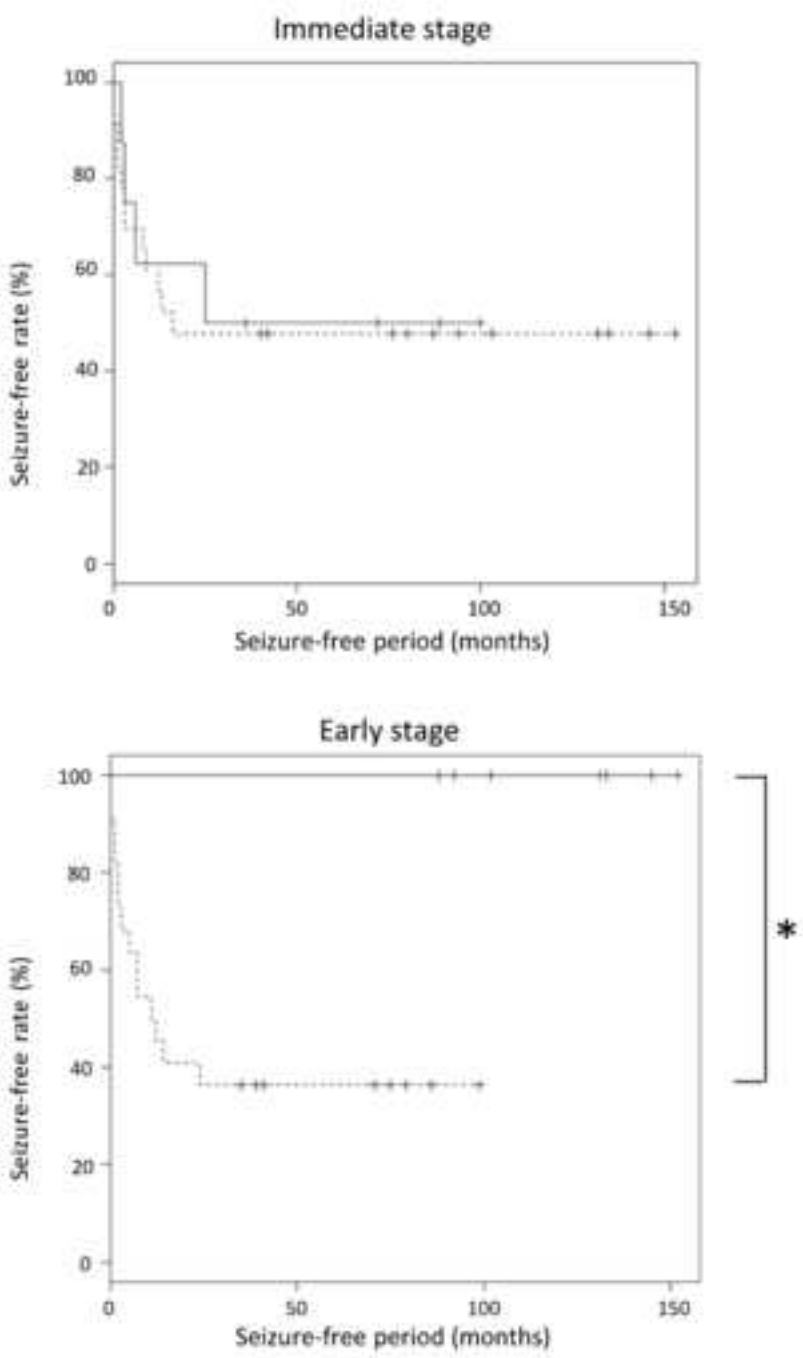

Figure legends

Figure 1. Location of epileptic discharges after completion of ACTH therapy

The number in parentheses is the number of patients. We classified the distribution of epileptic discharges on EEG after ACTH therapy as follows: “multifocal” (three or more independent foci), “occipital” (one focus or two independent foci limited to the parietal, post-temporal and occipital head areas) and “non-occipital” (one or two independent foci limited to the frontal, central, anterior temporal and midtemporal head areas).

()Number of cryptogenic patients * Number of patients with hypsarrhythmia

Figure 2. EEGs of a non-relapse patient and a relapse patient (sleep records)

(A) Immediate stage, (B) Very early stage (C) Early stage, (D) Middle stage

Non-relapse patient: (A) The epileptic discharges remained at the right parietal-posterior temporal-occipital head area and left frontal head area. (B) The epileptic discharges were observed in the right parietal and right frontal head areas. In addition to the spikes shown in this Figure, epileptic discharges in other areas, such as in the right posterior temporal-occipital and left frontal-anterior temporal head areas, were also observed. (C) and (D) All epileptic discharges disappeared.

Relapse patient: (A) The epileptic discharges were suppressed completely. (B) The epileptic discharges reappeared in the right occipital and left parietal head areas. In addition to these areas, epileptic discharges in other areas, such as in the left posterior temporal-occipital, bilateral midtemporal and right frontal head areas, were observed. (C) The epileptic discharges appeared in the left parietal and right frontal pole areas. We also observed multifocal epileptic discharges in the right parietal-occipital and right midtemporal head areas in

the same EEG recording. (D) Hypsarrhythmia evolved again.

Figure 3. Overall comparison of seizure-free rate between the group with spikes and the group without spikes

Black line: Patients with epileptic discharges. Dash line: Patients without epileptic discharges.

EEG results for the group with no epileptic discharges at the very early stage and the early stage showed a significantly higher seizure-free rate, whereas there was no significant difference in the seizure-free rate between the two groups at the immediate stage. * $p = 0.04$, ** $p < 0.001$

Figure 4. Comparison of seizure-free rate between the group with spikes and the group without spikes in symptomatic patients

Black line: Patients with epileptic discharges. Dash line: Patients without epileptic discharges.

The group with no epileptic discharges on EEG in the early stage showed a significantly higher seizure-free rate, whereas there was no significant difference in the seizure-free rate between the two groups in the immediate stage and the very early stage. * $p = 0.0091$