

Topographic EEG Analysis in Two Patients with Basilar Thrombosis

A. Kamondi and I. Szirmai

Key Words

Locked-In Syndrome
Sensory Stimulation
Topographic EEG

INTRODUCTION

Thrombosis of the basilar artery is the most frequent cause of locked-in syndrome. In almost half of the cases the EEG showed rhythmic activity in the alpha frequency band with reactivity to photic drive or other sensory stimuli.¹ About 30% of the EEGs demonstrated slow or poorly organized background activity; low amplitude fast patterns were also found.^{2,3} Despite a nonreactive alpha pattern reported by Jacome and Morilla-Pastor⁴ patients were found to be alert but with severely restricted motor function. Polysomnographic studies revealed disturbances both in REM and non-REM sleep.⁵⁻⁷ Focal signs were described only in head injured patients.⁸ According to the previous literature, analysis of EEG concomitants of locked-in syndrome was exclusively visual.

We present spectral analysis and EEG mapping of two patients with basilar artery occlusion. One of them exhibited classical signs of locked-in syndrome with EEG reactive to sensory stimuli. The other developed permanent vegetative state and a nonreactive alpha pattern. Quantitative analysis was expected to increase the validity of estimation and testing of EEG reactivity.

METHODS

A 16 channel EEG was recorded using the conventional 10-20 system. The Cz electrode served as reference. Quantification of EEG was done with an REEG-16 mapping system (MetLog, Hungary). The EEG was digitized with 64/s frequency and analysis interval was 4s. Data were stored on disc for off-line analysis. Binocular photic driving and verbal stimulation were used for activation. The following verbal instruction was given the patient: "Every time I say 'NOW,' please try to move your right hand."

The patient signaled the perception of command by blinking.

Methods of statistical analysis used were:

1. *Peak power frequency (PPF) analysis.*
2. *Relative power mapping:* linear power values of selected frequency bands divided by the mean power of the total frequency range (0.25-25Hz).

3. *Regional power fields:* averages of absolute power values calculated at 3 electrode positions of the posterior (O2-T6-P4; O1-T5-P3) and precentral (T4-C4-F8; T3-C3-F7) regions.

4. *Event related changes* of alpha and subalpha power in occipital and precentral fields were averaged during five consecutive trials of movement intention. The sampling of each trial started 4 s prior to the verbal stimulus and lasted 10 s. Change of alpha and subalpha power was calculated in 500 ms steps.

5. *Time sequences of absolute power and power ratios* of 30 s EEG segments were analyzed at symmetrical electrode positions.

Power asymmetries and effect of sensory stimulation were tested using Student's *t*-tests; *p* < 0.05 was regarded as significant.

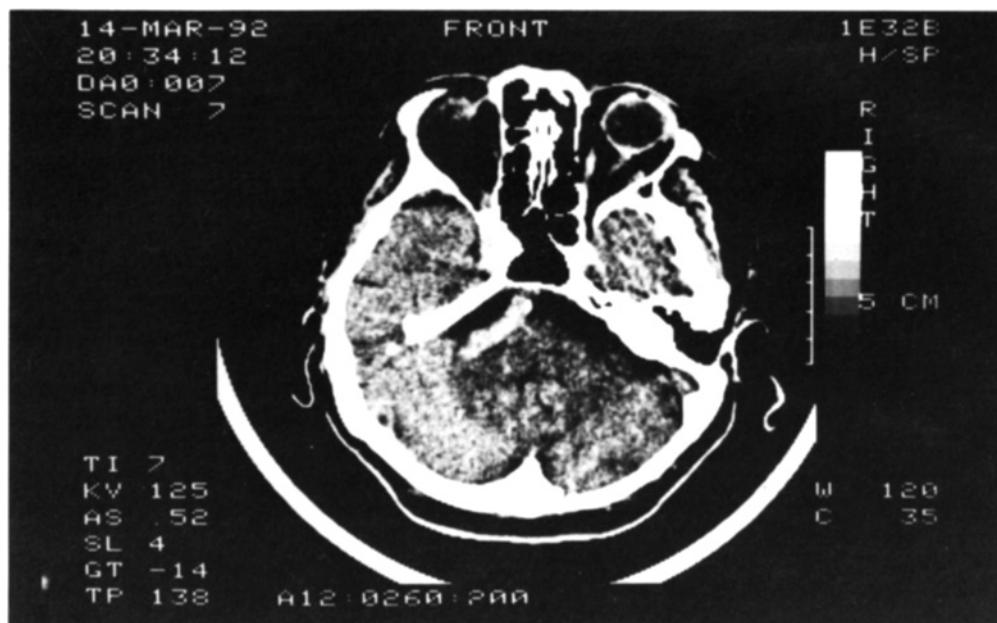
CASE REPORTS

Case 1

A 65-year-old woman suffered left hemifacial spasm and hypacusis 1 year prior to admission. CT scan revealed "dolichoectasia of the basilar artery" and several bilateral lacunae of the hemispheric white matter. The present admission was preceded by sudden vertigo, nausea, vomiting and ataxic gait. The neurologist found horizontal nystagmus, right central facial paresis, hemi-hypesthesia, and weakness of the right arm. Some hours later the symptoms

Anita Kamondi, M.D., is a Resident, and Imre Szirmai, M.D., Ph.D., is Professor at the Department of Neurology, University Medical School of Pécs, Hungary.

Requests for reprints should be addressed to I. Szirmai, M.D., Ph.D., Department of Neurology, University Medical School Pécs, Rét u.2. Pécs, 7624 Hungary.

**Figure 1.**

CT scan from Case 1. Calcification of widened left vertebral artery.

severely progressed; flaccid tetraparesis developed, painful stimuli evoked minimal flexion of both arms, and bilateral Babinski sign could be elicited. The patient was mute but responded to verbal commands with blinking. Transient skew deviation and later conjugate ocular deviation to the right were observed. The patient expired on the fifth day of intensive care because of cardiac arrest. CT scan demonstrated an enormously widened, calcified left vertebral artery (Figure 1) and dolichobasilar artery 1.5 cm in diameter. Hypodensity in the brain stem was not visualized. Multiple infarctions were additionally found in the left occipital and the right parietal white matter.

Autopsy

Enlarged vertebral and basilar arteries with calcified atherosclerotic plaques, widened left posterior communicating artery and recent thrombosis in the right vertebral artery were found. The base of the pons was softened. In the microscopic slides of frozen sections multiple well-circumscribed infarcts were found in both posterior thalamic regions.

Case 2

A 53-year-old man was admitted to a cardiology center because of dizziness and "collapses." A cardiac arrhythmia had been known for sev-

eral years. After transient loss of consciousness, speech disturbance and weakness of the right arm developed. Three hours later the patient became comatose, had tetraparesis, and pinpoint pupils were observed. Doll's head manoeuvre failed to deviate the eyes to either side. Extension-adduction spasm to painful stimuli and bilateral Babinski sign could be elicited. CT scan visualized no hypodensity in the brain stem. Angiography found occlusion of the basilar artery. The patient expired on the third day due to cardiac arrest.

Autopsy

The basilar artery was filled by a recent thrombus. Approximately 80 percent stenosis of left posterior cerebral artery caused by an atherosclerotic plaque was found. The right occipital pole and the medial surface of the temporal lobe were softened. Histopathological examination revealed a recent infarct in the central part of the ponto-mesencephalic region and the basis pontis with left predominance.

RESULTS

Case 1

Routine and computerized EEG analyses were performed 2 days prior to death. The visual reading of bipolar EEG did not detect asymmetry in the frequency of rhythmic com-

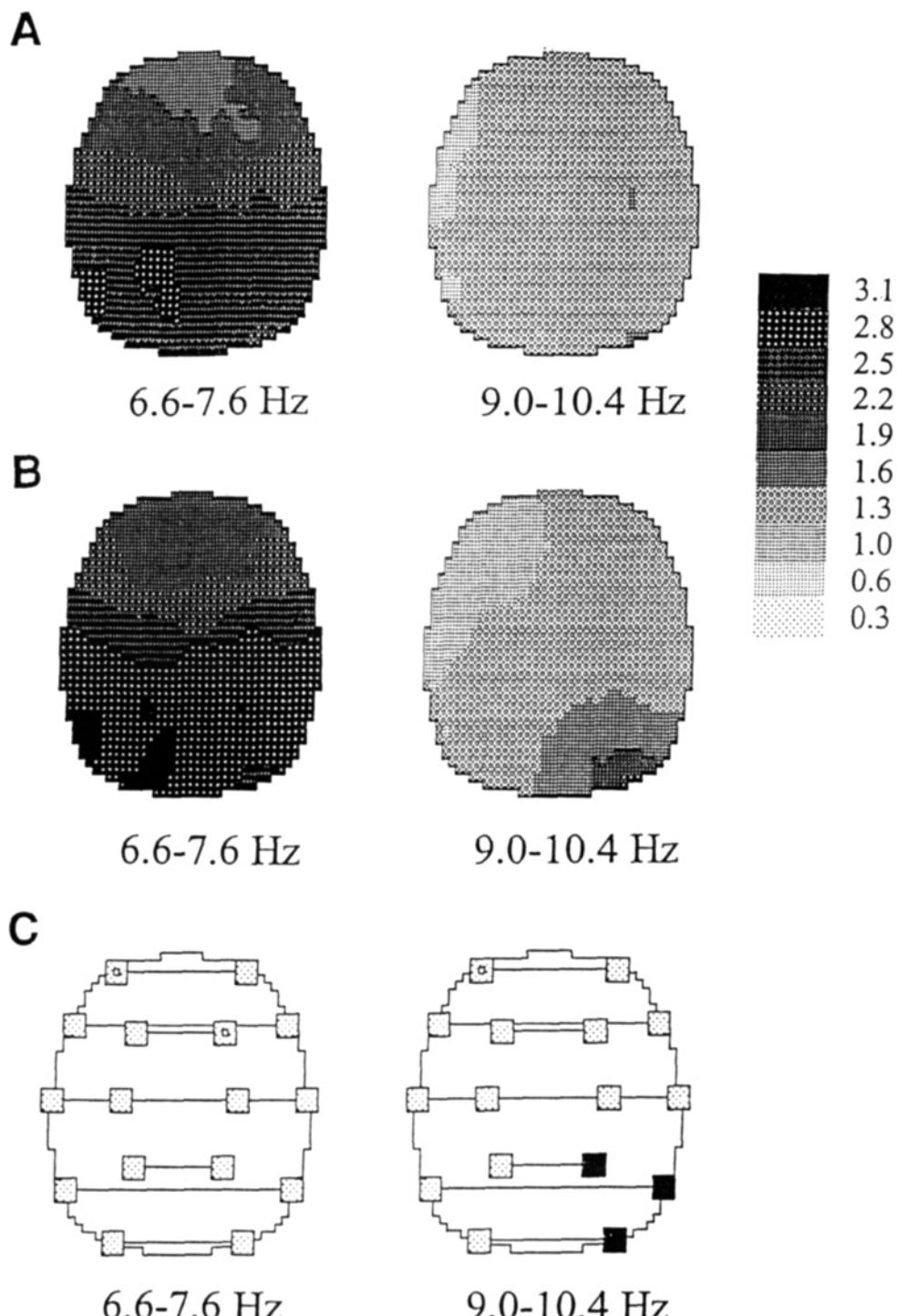


Figure 2. Effect of 10 Hz photic drive on alpha power. Case 1.

A: relative power mapping of control epochs at rest;

B: 10 Hz photic drive;

C: Student's *t*-test analysis for absolute power values.

Significant ($p < 0.01$) power increase in the alpha domain represented by filled squares.

Table 1

Case 1. Occipital power field asymmetries during rest and activation.

Averages of Linear Alpha Power in the Occipital Field		
	P4, T6, O2	P3, T5, O1
Control	6701 ± 1447	6787 ± 1183
10 Hz stimulation	8437 ± 1100*	6352 ± 1136
7 Hz stimulation	5706 ± 1015	5478 ± 1311
Verbal command	8075 ± 1327*	7033 ± 1524
Averages of Linear Subalpha Power in the Occipital Field		
	P4, T6, O2	P3, T5, O1
Control	10654 ± 1893*	12400 ± 2931
10 Hz stimulation	12392 ± 2401*	15488 ± 3498
7 Hz stimulation	10746 ± 2467*	12257 ± 2640
Verbal command	9325 ± 2012*	14269 ± 3803

* = $p < 0.005$.

ponents, but the monopolar derivation, with Cz reference electrode, showed higher amplitude background activity on the left side. Resting EEG, epochs of 7 Hz and 10 Hz photic stimulation and EEG epochs during verbal stimulation were computed. Each of the EEG segments were 1 minute in length. PPF analysis demonstrated a peak at 9.7 Hz on the right and 7.1 Hz on the left. EEG maps showed significantly higher field power in the alpha domain (9-10.4 Hz) on the right side and in the subalpha domain (6.6-7.6 Hz) on the left side. Ten Hz photic stimulation increased the alpha power significantly at the O2, P4 and T6 electrodes (Figure 2) compared to the resting values. Seven Hz photic stimulation did not have any effect on the alpha and subalpha power on either side.

Absolute alpha field-power averages of 1 minute EEG epochs were significantly higher during 10 Hz photo-stimulation and verbal commands on the right side (Table 1). Resting subalpha power was significantly higher on the left occipital field. Significant elevation of the left occipital field power was observed during intended movement and photic stimulation.

Event related decrease of absolute alpha power on both occipital and left anterior field was seen during intended movement (Figure 3). Reaction on the right anterior field was insignificant. Significant power reduction was observed in the subalpha domain on the left posterior as well as the anterior area. Randomly selected EEG epochs with equal lengths failed to show

similar sequential changes of alpha and subalpha power.

Case 2

EEG was performed 3 days prior to death. Visual analysis showed 9-10 Hz alpha spindles with left occipital dominance in the referential derivation (Figure 4).

Power spectrum analysis demonstrated two separate frequency peaks on both sides: one in the subalpha (7-8 Hz = SA) and one in the alpha (9-10 Hz = A) range. Resting alpha power was significantly higher on the left temporal and central regions in comparison with the right symmetrical positions. Verbal and painful stimuli did not influence the EEG activity; however randomly oscillating alpha spindles were observed. Nine Hz photic stimulation had no significant trigger effect.

Time sequence analysis demonstrated alternating activation of alpha and subalpha activity on the right side. In contrast to the visual evaluation of seemingly regular alpha bursting on both sides, there was a striking difference in the trend of power ratio (A/SA) fluctuation comparing the right and left hemispheric leads (Figure 5). Sequential analysis of averaged EEG epochs during verbal instructions showed no significant power response.

DISCUSSION

Preservation of rostral part of cortico-subcortical connections is considered to be a structural prerequisite of rhythmic and reactive EEG activity in organic brain diseases.⁹ In

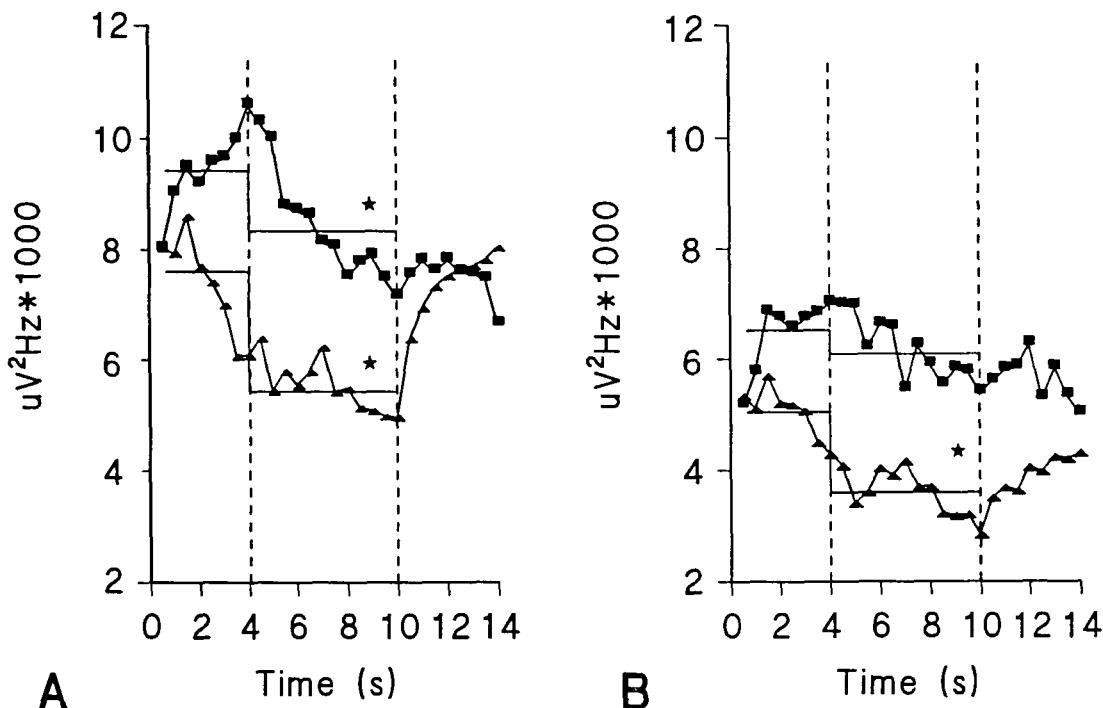


Figure 3. Event related field power changes in the alpha domain on the posterior and anterior electrode positions. Case 1.

A: Comparison of left (triangle) and right (square) posterior field power change.

B: Comparison of left and right anterior field power reaction. Stars indicate significant differences.

locked-in syndrome the EEG is usually reactive, but nonreactive "alpha coma" pattern has also been reported.⁴ The asymmetry of rhythmic EEG patterns can be subliminal for the visual analysis.¹⁰ In both of our cases the quantitative EEG analysis revealed statistically significant power asymmetries of rhythmic signals. This was presumably due to the ischemic infarcts in the territories of the posterior cerebral and posterior choroidal arteries.

Our approach to test the reactivity of EEG was based on the event related desynchronization (ERD) paradigm. According to Mecklinger and Bosel¹¹ the change of the alpha power can be used for the estimation of perceptual and cognitive procedures. ERD studies stress that elementary motor actions such as self-paced button press are preceded by regional desynchronization.¹² Similar changes can be measured using cognitive tasks such as planning of movement without execution.¹³ In the first case slight attenuation of the left hemisphere alpha generator was shown by a 1.5 Hz decrease of

PPF as compared to the right side. It was an unexpected finding that despite subalpha-theta dominance of left occipital region the reactivity to verbal stimulus was preserved.

The following observations serve as electrophysiological arguments for awareness in the patient in a locked-in state: event related field power was decreased significantly on the left anterior region compared to the right, the time course of alpha and subalpha power reduction after verbal stimulus was concordant with ERDs during planning of movements,¹⁴ and there was no statistically significant power change in randomly selected and averaged EEG segments. However, it must be emphasized that the "ERD" in our records is different from that of the healthy individuals. The power change cannot be defined as "desynchronization" but rather as "extinction" of background activity, that is, flattening of rhythmic signals which could be a kind of paradoxical activation.¹⁵

In comatose patients both alpha and subalpha activity imply a functioning thalamo-

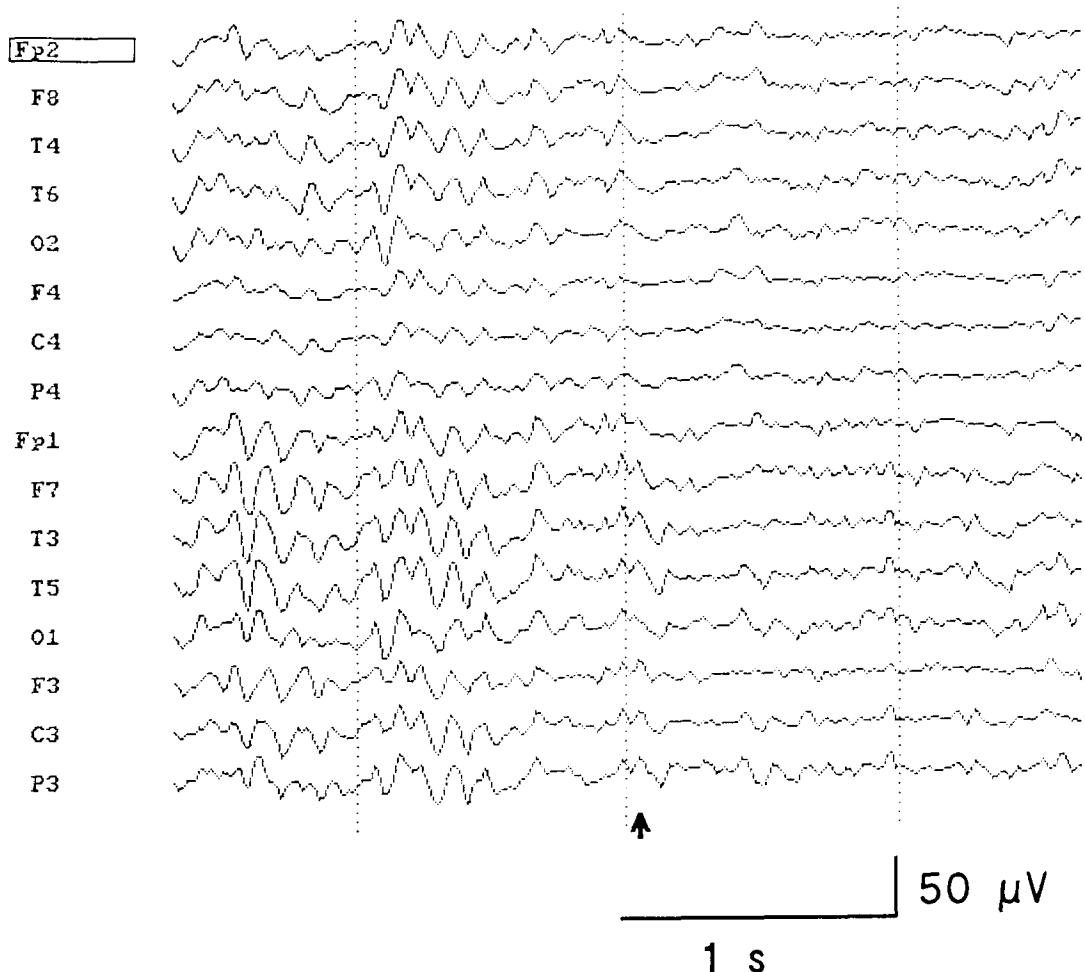


Figure 4. D-A converted EEG segment of Case 2. Arrow points to spontaneous desynchronization.

cortical system.^{16,17} In our second case spontaneous fluctuation of otherwise unreactive EEG activity was demonstrated. The underlying causes of sequential activation of alpha and subalpha generators over one hemisphere cannot be completely explained. We assume that partial preservation of the thalamo-cortical connections is enough to maintain the above mentioned activity. Histopathological findings proved the interruption of specific and non-specific ascending systems, and therefore sensory stimuli could not influence the thalamo-cortical relay stations. Pseudoperiodic fluctuation of rhythmic signals can be attributed to the reverberating electrical activity of "isolated brain." If cortical cells are relatively intact we may consider that such a patient retains the ability of

thalamo-cortical activation in spite of sensorimotor deprivation.

It is technically and ethically a hard task to obtain evidence of mental activity in completely paralyzed patients. Functional impairment of the rostral activating system is sometimes associated with minimal changes of background EEG that are hard to assess with visual analysis. Power ratios of selected narrow frequency domains sensitively reflect the EEG variability in time. The question remains open of how can one be sure that visual analysis estimates the "reactivity" of alpha patterns. Mathematical analysis of EEG including the ERD paradigm confirms the reactivity and variability of EEG signals and may provide a higher resolution to correlate awareness and electro-

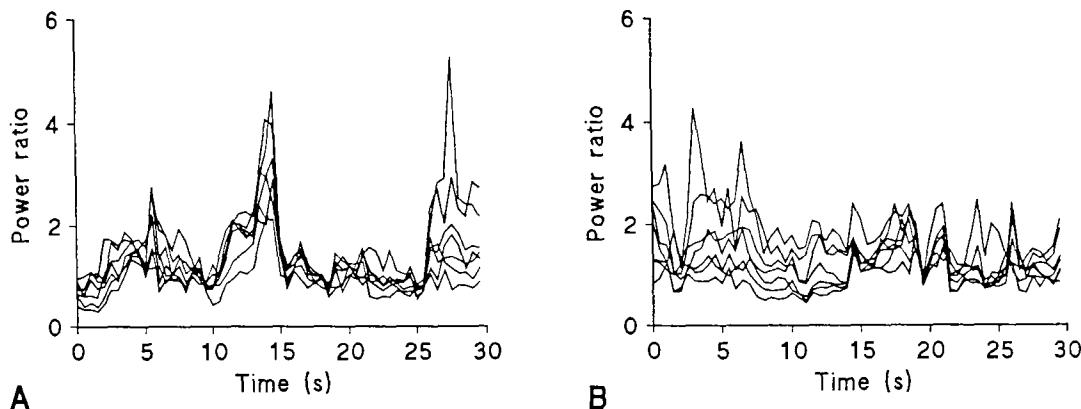


Figure 5. Time sequence variation of A/SA power ratios at seven electrode positions. Thirty seconds EEG using 1/2 s overlapping of 4 s analysis intervals. Case 2.

A: alternating alpha and subalpha power changes resulting in "peaks" of power ratios at the right derivations.

B: invariability of power ratios in time over the left hemisphere suggests random fluctuation of alpha and subalpha activity.

physiologic data in patients with extensive basilar artery thrombosis.

SUMMARY

The EEG activity of two patients with occlusion of the vertebral and basilar arteries was analyzed. Power maps, peak power frequency, and field power differences during both photic drive and verbal command were evaluated. Clinical findings of one patient fit the criteria of locked-in syndrome. Photic stimulation and event related desynchronization paradigm was used for testing the reactivity of EEG. Averaged EEG epochs during intended movement after

verbal command showed significant alpha and subalpha power reduction. Regional differences of EEG reactivity were assumed secondary to the underlying hemispheric infarcts. Awareness of the patient in a locked-in state was documented by EEG analysis. In the second case permanent vegetative state was associated with a nonreactive rhythmic alpha pattern. Time sequence analysis of power ratios showed spontaneous alternating activity of alpha and subalpha generators. The authors conclude that pseudo-periodic fluctuation of alpha activity reflects partial preservation of thalamo-cortical connections.

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