Seizure (2008) **17**, 514—523

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Frontal lobe epilepsy: Clinical characteristics, surgical outcomes and diagnostic modalities

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Received 28 May 2007; received in revised form 28 September 2007; accepted 23 January 2008

KEYWORDS
Frontal lobe epilepsy;
Presurgical evaluation;
Surgical outcome

Summary

Objective: To identify surgical prognostic factors and to characterize clinical features according to the location of the intracranial ictal onset zone of frontal lobe epilepsy (FLE) in order to assess the role of various diagnostic modalities, including concordances with presurgical evaluations.
Methods: We studied 71 FLE patients who underwent epilepsy surgery and whose outcomes were followed for more than 2 years. Diagnoses were established by standard presurgical evaluation.
Results: Clinical manifestations could be categorized into six types: initial focal motor (9 patients), initial versive seizure (15), frontal lobe complex partial seizure (14), complex partial seizure mimicking temporal lobe epilepsy (18), initial tonic elevation of arms (11), and sudden secondary generalized tonic—clonic seizure (4). Thirty-seven patients became seizure-free after surgery. Five patients were deleted in the analysis because of incomplete resection of ictal onset zones. The positive predictive value of interictal EEG, ictal EEG, MRI, PET, and ictal SPECT, respectively were 62.5%, 56.4%, 73.9%, 63.2%, and 63.6%, and the negative predictive value were 46.0%, 44.4%, 53.5%, 44.7%, and 51.7%. No significant relationship was found between the diagnostic accuracy of these modalities and surgical outcome, with the exception of MRI ($p = 0.029$). Significant concordance of two or more modalities was observed in

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1059-1311/$ — see front matter
doi:10.1016/j.seizure.2008.01.007

patients who became seizure-free ($p = 0.011$). We could not find any clinical characteristic related to surgical outcome besides seizure frequency. No definite relationship was found between the location of intracranial ictal onset zone and clinical semiology.

Conclusion: Although various diagnostic methods can be useful in the diagnosis of FLE, only MRI can predict surgical outcome. Concordance between presurgical evaluations indicates a better surgical outcome.

Introduction

Since the first successful surgery for frontal lobe epilepsy (FLE) was performed on a patient with a depressed frontal skull fracture,[1] the number of surgical resections to treat FLE has been increasing. Approximately 20% of patients with refractory partial epilepsy have seizures arising from the frontal lobes.[2] However, surgical intervention for FLE is less successful than for temporal lobe epilepsy.[3–5] The main reason for the poor outcomes is unclear. They may be due to a widespread epileptogenic zone, rapid spreading of ictal rhythm, large areas inaccessible to standard scalp electroencephalogram (EEG) or diverse seizure semiology.[6–9] Although this is still true, there has been improvement in the surgical treatment of FLE over recent years. The development of various neuroimaging techniques has improved understanding of FLE and allowed more patients to be considered for epilepsy surgery. However, reports on the roles of functional neuroimaging techniques in the diagnosis of FLE are still limited. Furthermore, no clear reports are available regarding the relationships between the results from various diagnostic tools and surgical outcomes.

A wide variety of entirely different types of seizures, including supplementary sensorimotor area seizures, frontal lobe complex partial seizures, and focal motor seizures, can occur with a frontal lobe origin.[9,10] However, it is not clear that the seizure types are specific to the region of seizure origin.

The main aim of this study was to assess the roles of various recently developed diagnostic modalities and to understand the relationships between the results obtained using these diagnostic modalities and surgical outcomes in a relatively large series of FLE patients. In addition, we analyzed the concordance between various presurgical evaluations in FLE and assessed the relationships between these concordances and surgical outcomes. We also attempted to characterize the clinical features of FLE and to determine any specific location associated with a specific seizure semiology.

Methods

Patients

Seventy-one consecutive patients diagnosed with FLE at Seoul National University Hospital from 1996 to 2003 were included in the study. The diagnostic criteria used for FLE were the presence of either a discrete lesion in the frontal lobe on magnetic resonance imaging (MRI) with a compatible ictal EEG, or the presence of an exclusive ictal onset zone in the frontal lobe confirmed by intracranial EEG.

There were 44 men and 27 women aged between 12 and 57 years. Age at seizure onset ranged from 1 to 49 years and the duration of illness from 3 to 34 years. All patients had intractable epilepsy, despite taking appropriate anticonvulsant medication. Surgery was performed in all patients. The postoperative follow-up duration was more than 2 years in all patients. Surgical outcome was analyzed using the Engel classification[11] and 'seizure-free (Engel class I)' or 'non-seizure-free (Engel class II, III, IV)' categorization.

We analyzed the prognostic values of each diagnostic modality by comparing the results of the postoperative seizure-free and non-seizure-free groups. We also analyzed the prognostic accuracy of each modality in patients that achieved a seizure-free status. In addition, we tried to identify the characteristic semiology of FLE according to the location of the intracranial ictal onset zone.

MRI

All patients underwent brain MRI. Standard MRI was performed on either a 1.0 or a 1.5 T unit (Signa Advantage; General Electric Medical Systems, Milwaukee, WI) with conventional spin-echo T-1 weighted sagittal and T-2 weighted axial and coronal sequences in all patients. Section thickness and conventional image gaps were 5 and 1 mm, respectively. Additionally, T-1 weighted 3D magnetization-prepared rapid acquisition gradient-echo sequences and 1.5 mm thick sections of the whole brain, and T-2 weighted fluid attenuated inversion recovery

(FLAIR) images with 3 mm thick sections were obtained in the oblique coronal plane of the temporal lobe. The angle of the oblique coronal imaging was perpendicular to the long axis of the hippocampus. The spatial resolution was approximately 1.0 mm × 1.0 mm (matrix, 256 mm × 256 mm; field of view, 25 cm). These sequences were performed in all subjects except for the FLAIR images, with the FLAIR sequence not performed in five subjects.

FDG—PET

PET was performed in 61 patients during the interictal period (no seizures for more than 24 h). Axial raw data were obtained on a PET scanner (ECAT EXACT 47, Siemens-CTI, Knoxville, TN, USA) 60 min after the intravenous injection of ^{18}F-fluorodeoxyglucose (FDG; 370 MBq). The acquisition time was approximately 20 min. The axial images were reconstructed using a Shepp—Logan filter (cutoff frequency, 5 cycles per pixel) and realigned in the coronal and sagittal planes. Spatial resolution was 6.1 mm × 6.1 mm × 4.3 mm. FDG—PET images were assessed by visual and statistical parameter mapping (SPM) analysis. For SPM analysis, spatial preprocessing and statistical analysis were performed using SPM 99 (Statistical Parametric Mapping 99, Institute of Neurology, University College of London, UK) as described elsewhere.[12]

Interictal and ictal SPECT

Ictal SPECT was performed on 43 patients during video-EEG monitoring. ^{99m}Tc was mixed with hexamethylpropylene amine oxime (HMPAO; 925 MBq) and injected as soon as a seizure started. Brain SPECT images were acquired within 2 h of the injection using a triple-head rotating Gamma camera (Prism 3000, Picker, USA) with a high-resolution fan beam collimator. Brain perfusion SPECT was acquired using the step and shoot method at 3° intervals using a 128 × 128 matrix. The complete acquisition lasted 15 min. Interictal SPECT was also performed to identify perfusion changes. SPM 99 implemented in Matlab 5.3 (Mathworks Inc., USA) was used to realign ictal and interictal SPECT images, and to spatially normalize these SPECT images into standard templates. A subtraction method was performed according to the method described previously.[12]

Video-EEG monitoring

In all patients, interictal/ictal scalp EEGs were recorded using a video-EEG monitoring system with electrodes placed according to the international 10—20 system with additional anterior temporal electrodes. We performed intracranial EEG monitoring in 64 patients with a combination of grids and strips. Grid and strip placements were determined using the results of the ictal scalp EEG, PET, ictal SPECT, and clinical semiology results. In all patients, at least three habitual seizures were recorded during scalp and two seizures for intracranial EEG monitoring. When necessary, preoperative and intraoperative functional mapping and intraoperative electrocorticography (ECoG) were also performed.

Decision to perform surgery

The criteria used for surgical resection were the presence of a discrete lesion on MRI with compatible video-EEG monitoring or an ictal onset zone confirmed by intracranial EEG. We also performed invasive monitoring of patients with a lesion on MRI in the following situations: (A) The lesion was near eloquent cortex; (B) the lesion might be cortical dysplasia; (C) there was a definite discrepancy between the results of the presurgical evaluations. In some patients with lesions on MRI, we performed simple lesionectomy and marginectomy when the results of ictal scalp EEG and semiology were well correlated with the location of the lesion.

Surgical resection in patients with normal MRIs was done according to following rules. First, the region showing clear ictal EEG onset before clinical ictal onset was included in the resection area. Second, the area with persistent pathologic delta slowings was also included, even though this area did not show an initial ictal rhythm. Third, areas satisfying the first or second rules should not be the essential eloquent cortex.

Evaluations of the diagnostic sensitivities of non-invasive studies

To exclude the possibility of the false localization of epileptogenic foci, the localizing and lateralizing values of individual modalities were analyzed only in seizure-free patients. Interictal/ictal scalp EEGs were reviewed and classified by two epileptologists after a consensus had been reached.

Ictal and interictal EEGs were classified as follows. (A) A localizing pattern of ictal onset rhythm/interictal spike was defined as a localized ictal rhythm/interictal spike confined to the electrodes of an epileptogenic lobe or two adjacent electrodes. (B) A lateralizing pattern was defined as an ictal onset rhythm/interictal spike in the electrodes of multilobes, including the epileptogenic lobe, but lateralized to the epileptogenic hemisphere. (C) A

Table 1 Demographic data and surgical outcomes

Patient characteristics	Seizure-free (38)	Persistent seizures (33)	*p* value
Sex (M:F)	23:15	21:12	0.811
Side of surgery (right:left)	16:22	21:12	0.096
2GTCS	30	27	0.500
Invasive study	34	30	0.580
Presence of possible cause	13	14	0.625
Age at surgery	26.2 ± 7.7	24.8 ± 8.5	0.380
Age at onset (years)	12.3 ± 5.8	11.0 ± 9.7	0.562
Duration of epilepsy (years)	13.9 ± 7.2	13.8 ± 6.6	0.365
Frequency of seizures (per month)	8.7 ± 13.3	23.3 ± 59.3	0.015

bilateral pattern (non-lateralizing) was defined as ictal onset rhythm/interictal spike in the bilateral hemisphere. (D) False localizing or false lateralizing were defined as an ictal onset rhythm/interictal spike in the electrodes of lobes other than the epileptogenic lobe in the ipsilateral hemisphere or in the hemisphere contralateral to the hemisphere containing the epileptogenic lobe.

FDG—PET and ictal—interictal subtraction SPECT images were reviewed by one experienced physician who was unaware of the clinical histories or the results of other presurgical evaluations. The SPECT images were also evaluated by side-by-side visual analysis. The results of the FDG—PET and SPECT images were classified as localizing (localized in the epileptogenic lobe), lateralizing (lateralized in the epileptogenic hemisphere including the epileptogenic lobe), non-lateralizing (normal or multilobar pattern in both hemispheres), or false localizing/false lateralizing (other lobe than the epileptogenic lobe). Statistical significance was assessed using chi-squared or Fisher's exact tests.

Pathological diagnosis

Tissue sections from cortical resections were immersion-fixed in 10% buffered formalin, embedded in paraffin, and stained with hematoxylin and eosin, Bielschowsky, and cresyl violet stains. A diagnosis of pathological cortical dysplasia was made according to the grading system of Palmini and Lüders[13].

Results

Demographic data

Ten patients had a history of febrile convulsion and nine had a history of meaningful head trauma. Another five patients had experienced encephalitis. The presence of any of these causes did not relate to surgical outcome. Other clinical characteristics such as age at surgery, seizure frequency, sex, presence of secondary generalized tonic—clonic seizure (2GTCS), presence of possible causes, duration of epilepsy, and side of surgery were not related to surgical outcome (Table 1). The only finding having statistical significance is the frequency of seizures (the number of seizures per month) (Table 1).

Surgical outcome

All patients underwent surgical treatment. Left frontal lobe surgery was performed in 34 patients. All patients were followed-up for at least 2 years after surgery. Thirty-seven (52.1%) became seizure-free, and another 4 patients (5.6%) rarely experienced seizures (Engel Class II). About 90% reduction of seizure was observed in 21 patients (29.7%) and no change after surgery was observed in 9 patients (12.6%).

Pathology

Pathological diagnosis was possible in 62 cases. According to Palmini classification, of 46 FCD patients (Table 2) there were 4 mild MCD, 26 FCD type 1A, 7 type 1B, 4 type 2A, and 5 type 2B.

Table 2 Pathology of surgical specimens

Pathology	Number of patients ($N = 62$)
Cortical dysplasia including microdysgenesis	46
DNET	4
Schizencephaly	2
Oligodendroglioma	2
Granuloma	2
Ganglioglioma	1
Scar	2
AVM	1
Cavernous hemangioma	1
Tuber	1

Table 3 The relationship between concordant lesion or epileptiform abnormalities on each diagnostic modalities and surgical outcomes

Presurgical evaluation[a]	Seizure-free	Persistent seizures
Interictal EEG (66)	10/37	6/29
MRI (66)[b]	17/37	6/29
PET (57)	12/33	7/24
Ictal SPECT (40)	7/21	4/19
Ictal scalp EEG (66)	22/37	17/29

Five patients were excluded because of incomplete resection of ictal onset zones. Values inside the parenthesis indicate the number of patients.

[a] Focal abnormality compatible with intracranial ictal onset zone.

[b] MRI was abnormal in 35 patients, including diffuse or multifocal abnormalities. The correct localization meant the unifocal lesion on MRI.

Prognostic accuracy and prognostic value of the various presurgical evaluations

We analyzed the prognostic value of the various diagnostic modalities with at least a 2-year follow-up (Table 3). Five patients were excluded in the analysis because the ictal onset zone could not be removed because of overlap with eloquent cortex, none of whom showed seizure-free outcome. Interictal EEG showed correctly localizing spikes in 10 of 37 patients who achieved a seizure-free status, and in 6 of 29 that did not ($p = 0.382$, OR = 1.42 (0.447—4.51 in 95% CI)). MRI was abnormal in 35 patients, including diffuse or multifocal abnormalities. Common findings were cerebromalacia (radiologically proven focal volume loss of gray or white matter) (nine patients), focal atrophy (six), cortical dysplasia (six), and dysembryoplastic neuroepithelial tumor (five). MRI correctly localized the unifocal lesion in 17 of 37 seizure-free patients, and in 6 of 29 non-seizure-free patients, which was statistically significant ($p = 0.029$, OR = 3.26 (1.08—9.86 in 95% CI)). FDG—PET correctly localized the lesion in 12 of 33 seizure-free patients, and in 7 of 24 non-seizure-free patients ($p = 0.390$, OR = 1.14 (0.38—3.54 in 95% CI)). Ictal SPECT was performed in 40 patients, and correctly localized the lesion in 7 of 21 seizure-free patients, and in 4 of 19 non-seizure-free patients ($p = 0.305$, OR = 1.88 (0.45—7.82 in 95% CI)). Ictal EEG correctly localized the lesion in 22 of 37 seizure-free patients, and in 17 of 29 non-seizure-free patients ($p = 0.572$, OR = 1.04 (0.39—2.78 in 95% CI); Table 3). Detailed results from the diagnostic modalities are summarized in Table 4. FDG—PET and ictal SPECT correctly lateralized the hemisphere in an additional 13 (6 of 33 seizure-free patients) and 11 (7 of 21 seizure-free patients) patients, respectively. Including the patients with lateralizing PET or SPECT in the localizing group, ictal SPECT results showed a marginal significance for predicting a good surgical outcome ($p = 0.103$), while FDG—PET results showed no significance ($p = 0.550$). The positive predictive value of interictal EEG, ictal EEG, MRI, PET, and ictal SPECT, respectively were 62.5%, 56.4%, 73.9%, 63.2%, and 63.6%, and the negative predictive value were 46.0%, 44.4%, 53.5%, 44.7%, and 51.7%, respectively.

Monitoring with subdural electrode performed in 54 patients including 5 patients who showed ictal onset zones containing eloquent areas and would be excluded in the following analyses. We analyzed intra cranial EEG data based on frequency (beta, alpha, theta or delta band) and spatial pattern. The spatial pattern was categorized as focal (involving <5 adjacent electrodes), regional (≥ 5 adjacent electrodes), or widespread (>20 adjacent electrodes). The frequency of initial ictal waves (beta waves were observed in 15 of 27 who achieved a seizure-free status and in 9 of 22 who did not; $p = 0.232$) the spatial pattern (initial focal onset of ictal discharges were observed in 8 of 27 who

Table 4 Diagnostic sensitivities of individual modalities in seizure-free patients

Diagnostic tool	Localizing	Lateralizing	Non-lateralizing	False localizing
MRI (37)	17	3	17[a]	0
Ictal scalp EEG (37)	22	3	9	3
Interictal EEG (37)	10	15	5[b]	7
FDG—PET (33)	12	6	9	6
Ictal SPECT (21)	7	7	2	5

[a] Seventeen non-lateralizing MRIs included 15 normal images and two cases of multiple lesions.

[b] No interictal spikes were detected in all five non-lateralizing interictal EEGs.

Table 5 Concordance of the five diagnostic modalities (interictal EEG, ictal scalp EEG, MRI, FDG—PET, and ictal SPECT) in the seizure-free and persistent-seizure groups in patients with complete resection of ictal onset zones

Concordance [a]	Seizure-free (37)	Non-seizure-free (29)
5	1	0
4	2	1
3	6	4
2	14	4
1	8	15
0	6	5

[a] Number of concordant diagnostic modalities.

achieved a seizure-free status and in 7 of 22 who did not; $p = 0.556$) did not correlated with postoperative outcome.

Concordance of individual modalities

Table 5 shows the concordance of interictal EEG, ictal scalp EEG, MRI, FDG—PET, and ictal SPECT in the group classification according to surgical outcome. The concordance of two or more modalities was observed in 23 of 37 seizure-free patients and 9 of 29 non-seizure-free patients. It was significantly observed in those that achieved a seizure-free status ($p = 0.011$, Fisher's exact test). When sequence of investigations were considered, MRI and interictal and ictal EEG were performed first, the concordance of two or more modalities between these three methods was observed in 15 of 37 seizure-free patients and 7 of 29 non-seizure-free patients, which showed no statistical significance ($p = 0.127$, OR = 2.14 (0.73—6.27 in 95% CI)). In the patients who underwent full diagnostic modalities including ictal SPECT and PET ($N = 35$), the concordance of two or more modalities was observed in 14 of 19 seizure-free patients and 7 of 16 non-seizure-free patients, which showed marginal significance ($p = 0.073$, OR = 3.6 (0.87—14.90 in 95% CI)).

Objective seizure manifestation

The most common seizure manifestation was complex partial seizure mimicking seizures of temporal lobe epilepsy (18 patients), followed by, initial versive seizure (15 patients), frontal lobe complex partial seizure (14 patients), initial tonic elevation of arms (11 patients), initial focal motor seizure (9 patients), and sudden secondary 2GTCS (4 patients) (Table 6). No definite and consistent relationship was found between the location of intracranial ictal onset zone and clinical semiology (Fig. 1). Versive seizures usually originated from the superior and middle frontal convexity. Complex partial seizures of the temporal lobe epilepsy type were from the middle and inferior temporal convexity or orbitofrontal area. The origins of the frontal lobe complex partial seizures were scattered throughout all sites of the frontal lobe. The origins of the focal motor seizures were not restricted to the motor cortex. Among the 11 patients with initial tonic arm elevation, a brief and sudden assumption of bilateral tonic posture (typical supplementary sensory motor area seizures; SSMA seizures) was observed in four patients whose intracranial ictal onset zones were associated with the superior or medial frontal areas.

Discussion

We could not find any relationship between specific previous history and surgical outcome. One previous study[14] found that a history of childhood febrile seizure was predictive of surgical outcome in FLE and suggested that childhood febrile seizure was strongly associated with temporal lobe epilepsy. However, we did not find this effect.

We examined 1.5 mm thick sections of the whole brain, and T-2 weighted and FLAIR images with 3 mm thick sections in the oblique coronal plane of the temporal lobe in all patients to detect hippocampal sclerosis. Because history of febrile convulsion was associated with medial temporal lobe epilepsy with

Table 6 Objective seizure manifestations

Semiology	Seizure-free (37)	Non-seizure-free (34)	Total
Focal motor with or without 2GTCS	6	3	9
Version with or without 2GTCS	6	9	15
CPS of temporal type with or without 2GTCS	8	10	18
Tonic arm elevation with or without 2GTCS [a]	6	5	11
FLCPS	8	6	14
Sudden 2GTCS	3	1	4

2GTCS: secondary generalized tonic—clonic seizure; FLCPS: frontal lobe complex partial seizure.
[a] Including four SSMA seizure patients.

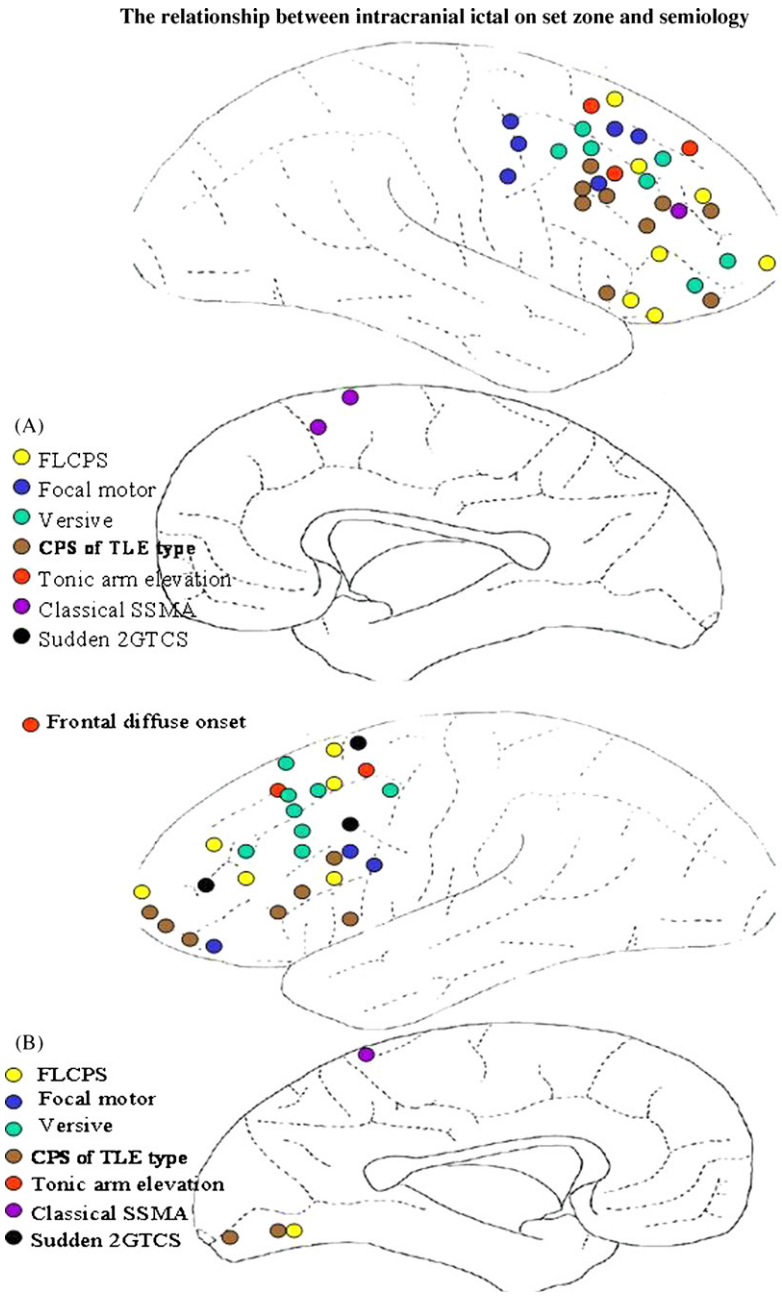

Figure 1 The relationship between the ictal semiology and the location of the intracranial ictal onset zone ((A) right and (B) left hemispheres). The intracranial ictal onset zone of each patient depicted in the figure was representative of the most active area or the central zone of the intracranial electrodes with ictal onset rhythm. Two patients (one assumed seizures with tonic elevation of left arm, and the other assumed sudden secondary generalized tonic–clonic seizures) had diffuse ictal onset zone in the frontal lobe.

hippocampal sclerosis, with this procedure we could exclude most of the medial temporal lobe epilepsy patients from our series.

Our study showed that only two clinical characteristics, the frequency of seizures and the presence of lesion on MRI, were related with surgical outcome.

Some previous reports also indicated that low seizure frequency was correlated with good outcome in temporal lobe epilepsy patients.[15,16] However, there was no previous result in FLE regarding surgical outcome associated with seizure frequency, and this is the first report showing an association of seizure frequency and surgical outcome on FLE, to our knowledge.

One previous study showed that secondary generalized seizures were related with poor surgical outcome,[17] whereas other studies, similar with our

study, did not find such a correlation.[18] Inclusion of more patients might resolve this issue.

The other clinical finding related to surgical outcome was the presence of a lesion detected by MRI. The resection of an epileptogenic lesion within an ictal onset zone is recognized as the most important factor for a good surgical outcome.[19–21] The majority of surgical series have suggested that the presence of a specific lesion usually leads to a favorable surgical outcome.[22–25] An important reason for an unfavorable operative outcome in patients with non-lesional neocortical epilepsy is the inherent difficulty of identifying the epileptogenic zone.[26] In our result, the predictive value of MRI on seizure freedom and persistent seizures were 73.9% and 53.5%, respectively. Therefore, MRI is relatively good at predicting the prognosis of FLE. The predictive value of the other modalities were lower than that of MRI.

Our previous reports including the whole spectrum of neocortical epilepsy syndromes or occipital lobe epilepsy showed that focal FDG–PET hypometabolism or the presence of focal interictal spikes was also related to good surgical outcomes.[27,28] Localization of FDG–PET and interictal spikes on EEG were also correlated to a seizure-free outcome in cryptogenic neocortical epilepsy.[29] This finding stresses that the results of presurgical evaluations should be cautiously interpreted according to the various epileptic syndromes or different situations. Differences in size and accessibility of the different lobes, and variable spreading speed and pathways could be the reasons for the differences in outcomes. From the result of our study, false localization of epileptogenic area was common, especially high for SPECT and PET. Because of the rapid spread of ictal discharge, seizure onset zone may be falsely localized on ictal SPECT. However, the mechanism for false localization in FDG–PET is unclear. Hypometabolism at other area beside seizure focus may be caused by physiologic dysfunction in regions functionally associated with frontal lobe or synaptic alteration.[12,30]

Outcome with regard to seizure control after frontal lobe surgery is generally poor.[3–5,31] Only a minority became seizure-free after surgery, which may be due to inherent difficulties in localizing epileptogenic foci in non-lesional cases, widespread epileptogenic zones, rapid propagation, wide areas of the frontal lobe, and the presence of eloquent cortex. However, advances in neuroimaging and improved understanding of FLE have allowed more patients to be considered for epilepsy surgery and may have improved surgical outcomes.[9,10,32] The surgical outcomes in our series are similar to those in recent reports.

A hypermotor type of complex partial seizure, which has been described repeatedly in association with FLE,[28,33–37] was observed in 14 patients. Any area of frontal lobe could generate this type of seizure. Typical complex partial seizure mimicking a temporal lobe origin was observed in 18 patients of our series. The usual locations generating this seizure were the inferior frontal or orbitofrontal areas; however, the middle frontal lobe was also associated with this type of seizure. Version seizure, with or without 2GTCS, was observed in 15 patients. The direction of version was contralateral in 14 of these 15 patients. Version has usually been interpreted as suggestive of seizure onset contralateral to the direction of version,[38–41] despite some reports that have found different results.[41,42] The diagnostic criteria of version may affect the results. Our diagnostic criterion of version is that there should be clonic or tonic head and eye deviations that are unquestionably forced and involuntary, resulting in sustained and unnatural positioning of the head and eyes.[38] One previous study reported that head version contralateral to the operated side of the frontal lobe was associated with poor outcomes, and suggested the explanation may be rapid activation of widespread cortex evoking version.[27] However, we did not observe this relationship.

Characteristic SSMA seizures (assuming fencer's posture) were observed in four patients. Three of them had an ictal onset zone in the SSMA area. One patient whose ictal onset zone was located in the middle frontal lobe showed typical SSMA seizures. In addition to typical SSMA seizures, tonic arm elevation as an initial seizure manifestation was found in another seven patients. Focal motor seizure could be generated by an ictal onset zone located in the central motor cortex and other areas. Even seizures originating from the frontal pole could cause initial focal motor phenomena.

Among the other diagnostic tools, only MRI could predict surgical outcome. However, the concordance between diagnostic modalities was also a significant factor in predicting surgical outcome. Not all the patients could underwent ictal SPECT and PET by many reasons such as nocturnal clustering of seizures and economical problem. There should also be a selection bias underlying prognostic accuracy of these studies. For example, the patients with structural lesion on MRI with concordant ictal EEG could be easily recruited to epilepsy surgery irrespective of the results of SPECT and PET. Among the patients who underwent full diagnostic work-up, two or more concordance was more observed in those who achieved a seizure-free status with marginal significance. The localization of the presumed epileptogenic zone by different methods based on

different physiologic mechanisms could enhance the possibility of finding the true epileptogenic zone.

In conclusion, our study shows that the likelihood of a surgical outcome being favorable as two or more of tests were concordant with respect to epileptogenic foci and when a focal abnormality is seen on MRI. Several semiology of seizures can be grouped. However, any of these groups does not have a specific seizure onset site.

Conflicts of interest

The authors have reported no conflicts of interest.

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