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Seizure Control in Patients with Extratemporal Lobe Epilepsy

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Objective : This study was designed to analyze seizure outcome and to investigate the prognostic factors for predicting seizure outcome according to the preoperative evaluations, surgical procedures, topectomy sites and histopathological findings in patients with extratemporal lobe epilepsy (ETLE).

Methods : This study comprised 63 patients with ETLE who underwent surgery. Preoperative evaluations included semiologic analysis, chronic video-EEG monitoring, and neuroimaging studies. Surgical procedures consisted of topectomy in 51 patients, corpus callosotomy in 9, functional hemispherectomy in 2, and vagus nerve stimulation (VNS) in 1. Histopathological findings were reviewed. Postoperative seizure outcomes were assessed by Engel's classification at the average follow up period of 66.8 months. Chi-square test was used for statistics.

Results : Total postoperative seizure outcomes were class I in 51 (80%) patients, class II in 6 (10%), class III in 6 (10%). Patients with structural abnormalities on neuroimaging study showed class I in 49 (88%) patients ($p<0.05$). Patients with focal and regional ictal EEG onset revealed class I in 47 (90%) patients ($p<0.05$). Semiologic findings, surgical procedures, topectomy sites and histopathological findings did not show statistical correlation with seizure outcome ($p>0.05$).

Conclusion : A good seizure outcome was obtained in patients with ETLE. The factors for favorable seizure outcome are related to the presence of structural abnormalities on neuroimaging study, and focal and regional ictal EEG onset.

KEY WORDS : Epilepsy · Partial treatment outcome · Seizure · Prognostic factor.

Introduction

Epilepsy is one of the most common neurological disease, with a prevalence of 0.5-1.0% and with an estimated lifetime cumulative incidence of 3%[19)]. The main goals of epilepsy treatment are freedom or substantial relief from seizure and improvement of quality of life[2,10,19)]. Antiepileptic drugs are usually given as the first therapeutic option. However, 20-30% of subjects with seizure are refractory to medical or surgical treatments. Overall, about 30-40% of patients with epilepsy have medically intractable seizures, 50% of whom are candidates for epilepsy surgery[8,18,19)]. Approximately 40% of patients with intractable epilepsy suffer from generalized seizure, and 60% from focal (partial) seizure[19)]. About 55% of patients with focal epilepsy, which originates from a circumscribed cerebral region, have temporal lobe epilepsy (TLE), and the remaining 45% of patients have extratemporal lobe epilepsy (ETLE)[19)]. Focal seizure of extratemporal origin is predominantly associated with frontal lobe epilepsy[2,3,9,19)].

Surgery for epilepsy is now an established, effective means for treating patients with intractable seizure[2,8,11,17)]. In patients undergoing surgery for extratemporal foci, overall outcome has been found to be poor (50-70%), compared to patients with TLE considering that more than 80% are seizure-free[2,3,5,8,13,15,17)]. Potential operative complications may increase in individuals with ETLE, because of functional cortex involvement and the need for a large cortical resection[2,3,7,20,21)].

Many studies have been reported to identify factors that predict the outcome in seizure control after ETLE surgery. Previous investigators have suggested the presence of abnormal magnetic resonance imaging (MRI) lesions or focal neoplastic lesions, ictal electroencephalogram (EEG) pattern, histopathologic findings, and operative methods or lesion sites as prognostic factors. We made an effort to visualize the

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epileptogenic lesions using multimodal neuroimaging studies (MRI, positron emission tomography (PET), single photon emission computed tomography (SPECT), and 3 dimensional (3D)-surface rendering with MRI image), and performed chronic video-EEG monitoring, various appropriate surgical procedures, and postoperative histopathological analysis.

The aim of this study was to evaluate seizure outcomes and to identify prognostic factors including the results of various preoperative evaluation modalities (neuroimaging study, semiology, and ictal EEG onset), surgery (procedure and site), and histopathology in patients with ETLE excluding tumors or vascular malformations.

Materials and Methods

Patients

We analyzed 63 consecutive patients with intractable ETLE who underwent surgical treatment between October 1998 and October 2005. The mean age of patients was 24.3 years (range, 5 months to 57 years). There were 41 males and 22 females. The age at the seizure onset ranged from 1 month to 34 years (mean age, 10.1 years), and the duration of illness ranged from 1 month to 54 years (mean duration, 15.1 years). The frequency of seizure ranged from 20 times/day to 12 times/year (mean frequency, 63.3 times/month), and ictal duration ranged from 10 second to 15 minutes (mean duration, 2 minutes). All patients suffered from intractable epilepsy, despite proper anticonvulsant medication. Patients with tumor or vascular malformation were excluded from this study.

Neuroimaging study (MRI, 3D-surface rendering with MRI)

All patients underwent brain MRI (Siemens 1.5 SP system, Magnetom vision, Erlargen, Germany) with conventional T1-weighted, T2-weighted axial, coronal and sagittal. In addition, T2-weighted fluid attenuated inversion recovery (FLAIR) coronal images were obtained. Brain 3D-surface rendering with MRI image was obtained in all patients as well. Before 2002, we used Allegro (ISG technologies Inc. Toronto, Canada) to obtain 3D-surface rendering image, and since 2002, we have used Voxelplus (Mevisys, Seoul, Korea).

Functional neuroimaging study

Interictal PET was performed in 44 patients by using 18F-fluorodeoxyglucose (FDG). Interictal SPECT was carried out in 22 patients using ^{99m}technetium hexamethyl propylene-amine-oxime (HMPAO) for the assessment of radiotracer concentrations in both hemispheres and quantitative differences in ictal/interictal SPECT. However, of 22 patients undergoing interictal SPECT, ictal SPECT was carried out in only a few (7) patients.

Chronic video-EEG monitoring with surface and intracranial EEG

Interictal and ictal scalp EEGs were recorded using a video-EEG monitoring system (Telefactor, West Conshohoken, PA, USA) with electrodes placed according to the International 10-20 system and with an additional sphenoid electrode. We used a combination of subdural grid (SDG) electrodes and depth electrodes for intracranial EEG, and scalp EEG. Surface scalp EEG was recorded in all patients. In patients with diffuse bilateral ictal EEG onset in scalp EEG, and in patients with incongruency between neuroimaging study, semiology and ictal EEG onset zone, intracranial EEG were recorded with SDG electrodes in 47 patients and depth electrodes in 4 patients. At least 7 habitual seizures were recorded during scalp and intracranial EEG monitoring.

Surgery and Histopathology

The resection margin was defined according to the data of ictal EEG onset zone of subdural grid EEG, and the location of eloquent area. In patients with concordance between structural abnormality and ictal EEG onset zone, structurally abnormal area is totally resected except eloquent area. In patients with diffuse ictal EEG onset in SDG EEG, resection margin included the area showing ictal onset and epileptogenic discharges in intraoperative electrocorticograpaphy (ECoG) electrographically, and the area showing abnormal cortical consistency during resection.

We made an effort to preserve eloquent area according to the result of anatomical and functional intraoperative mapping. Intraoperative motor mapping was performed in 30 patients, and 11 patients underwent motor and speech mapping under awaken anesthesia. In patients with drop attack or diffuse ictal EEG onset, corpus callosotomy was done. In patients showing supplementary sensorimotor area (SSMA) seizures with diffuse ictal EEG onset in the frontal convexity and SSMA, and rapid propagation of the ictal EEG onset to the contralateral hemisphere, so that the potential epileptogenic zone will be left, topectomy including frontal convexity and SSMA, and corpus callosotomy were performed.

In patients who showed eloquent area ictal EEG onset, we did multiple subpial transection (MST) or vagus nerve stimulation (VNS). Appropriate variable surgical procedures were performed in each patients. Unifocal topectomy was performed in 27 (43%) patients, multifocal topectomy in 21 (34%), corpus callosotomy in 9 (15%), topectomy with corpus callosotomy in 2 (3%), functional hemispherectomy in 2 (3%), topectomy with MST in 1 (1%) and VNS in 1 (1%). All the operations were performed by the same neurosurgeon. During and after the resection of epileptogenic zone, intraoperative ECoG was done in 14 patients to predict of postoperative prognosis. All topectomy specimens were reviewed postoperatively for histopathological diagnosis. Histopathological grading of cortical dysplasia (CD) includes grade 1 as cortical dyslamination only, grade 2 is grade 1 plus giant dysplastic neurons, and grade 3 is grade 2 plus giant bizarre astrocytes (balloon cell). Milder microscopic dysplasia with subtler cytopathology were variously termed CD occult.

Follow-up and outcome evaluation

Follow-up information was obtained in all patients for at least 12 months after surgery. The mean follow-up period was 66.8 months (range, 12 to 108 months). Seizure outcome was classified into 4 groups according to the Engel's seizure outcome classification. We considered Engel's class I and II as favorable outcome, and Engel's class III and IV as poor outcome.

Analysis

We assessed seizure outcome in ETLE patients and related prognostic factors in terms of structural abnormalities on neuroimaging study, ictal EEG onset, semiologic findings, histopathological findings of topectomy specimens, surgical procedures, and topectomy sites. We also assessed the relationship between seizure outcome and its concordance with presurgical evaluation. Chi-square test was used for statistics.

Results

Neuroimaging study (MRI, 3D-surface rendering with MRI)

MRI identified structural abnormalities in 43 patients and no abnormalities in 20 patients. Structural abnormalities included schizencephaly, encephalomalacia, atrophic changes, ischemic lesions, porencephaly, macrogyrus, ulegyria, and cortical dysplasia.

Of 20 patients without structural abnormalities on MRI, 13 revealed gyral disorganization on 3D-surface rendering with MRI. Consequently, 56 patients revealed structural abnormalities on neuroimaging study.

Functional neuroimaging study

In interictal PET, 19 (43%) of 44 patients showed hypometabolic areas corresponding to lesions on neuroimaging study. In interictal and ictal SPECT, only 5 (23%) of 22 patients showed hypoperfusion or hyperperfusion areas compatible with lesions on neuroimaging study.

Consequently, functional neuroimaging study (SPECT, PET) was not useful in the localization and lateralization of epileptogenic zone in our ETLE patients. So, we excluded this method to identify prognostic factors with statistics.

Chronic video-EEG monitoring with surface and intracranial EEG

Ictal EEG onset recordings on chronic video-EEG monitoring with surface and intracranial electrodes were obtained in all patients. Focal ictal EEG onset was recorded in 27 (43%) patients, regional ictal EEG onset in 25 (40%), and diffuse bilateral ictal EEG onset in 11 (17%).

Semiology

Semiologic findings on chronic video-EEG monitoring were obtained in all patients. Complex partial seizure (CPS) was observed in 46 (73%) patients, SSMA seizure in 14 (23%), drop attack in 2 (3%), and simple partial seizure (SPS) in 1 (1%).

Surgery

Unifocal topectomy was performed in 27 (43%) patients. Frontal lobe topectomy was performed in 15 (31%) patients, parietal lobe topectomy in 9 (19%), occipital lobe topectomy in 1 (2%), SSMA topectomy in 2 (4%). Twenty one (34%) patients had multifocal topectomy. Near total corpus callosotomy was performed in 9 (15%) patients, topectomy with corpus callosotomy in 2 (3%), functional hemispherectomy in 2 (3%), topectomy with MST in 1 (1%), and VNS in 1 (1%).

Histopathology

Of 51 patients undergoing topectomy, CD was observed in 38 (74%) patients. CD occult was observed in 2 patients, CD 1 in 3, CD 2 in 22, and CD 3 in 11. Ischemic insult was observed in 5 (10%) patients, reactive gliosis in 5 (10%), encephalitis in 2 (4%), and trauma in 1 (2%).

Seizure outcomes

Overall seizure outcomes of ETLE patients are given in (Fig. 1). Of 63 patients, Engel's class I was shown in 51 (80%) patients, class II in 6 (10%), class III in 6 (10%), and none showed class IV.

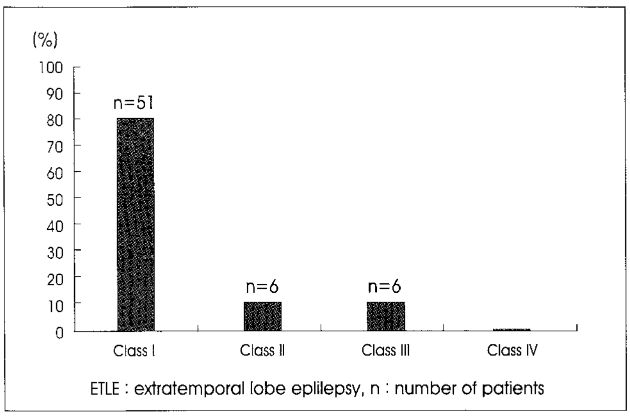


Fig. 1. Overall seizure outcomes of ETLE patients (n=63).

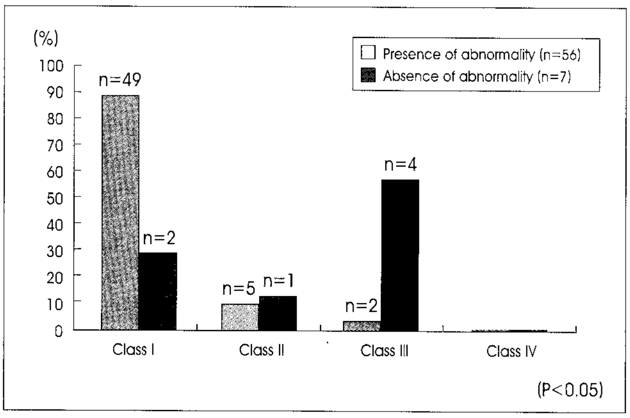


Fig. 2. Relationship between seizure outcomes and presence of structural abnormalities on neuroimaging study in ETLE patients (n=63).

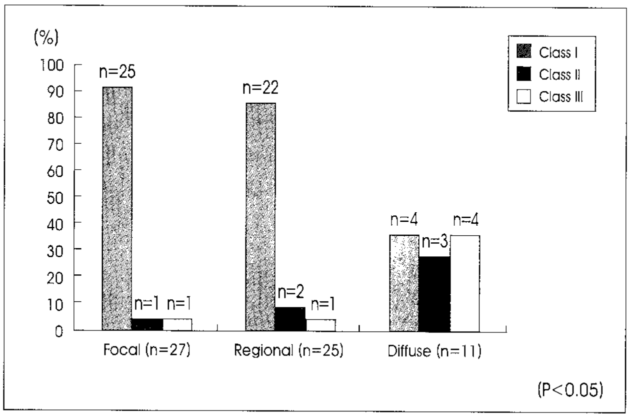
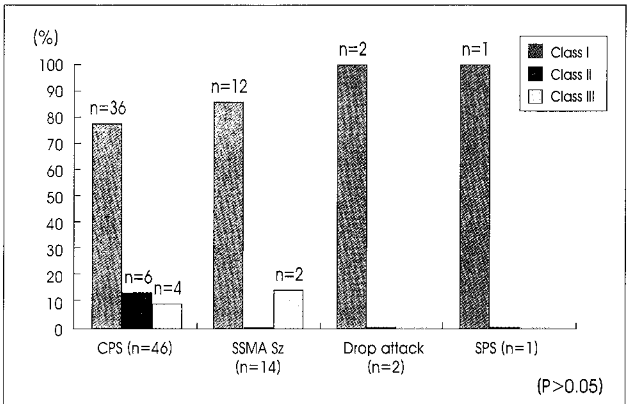


Fig. 3. Seizure outcomes analysis according to Ictal EEG onset in ETLE patients (n=63).

Patients with Engel's class III showed non-visualization of abnormalities on MRI, presence of schizencephaly, diffuse encephalomalatic change, and diffuse ictal EEG onset.

The relationship between seizure outcomes and presence of structural abnormalities on neuroimaging study was investigated (Fig. 2). Out of 56 patients with structural abnormalities on neuroimaging study, seizure outcomes showed Engel's class I in 49 (88%) patients, class II in 5 (9%) patients, and class III in 2 (3%) patients. Of 7 patients without structural abnormalities on neuroimaging study, seizure outcomes showed Engel's class I in 2 (29%) patients, class II in 1 (14%), and class III in 4 (57%). Patients with structural abnormalities on neuroimaging study showed more favorable seizure outcome than those without structural abnormalities on neuroimaging study, and there was definitely statistical significance between them ($P<0.05$).

Seizure outcomes were analyzed according to ictal EEG onset are summarized in Fig. 3. Of 27 patients with focal ictal EEG onset, Engel's class I was observed in 25 (92%) patients, class II in 1 (4%), and class III in 1 (4%). Of 25 patients who had regional ictal EEG onset, Engel's class I was observed in 22 (88%) patients, class II in 2 (8%), and



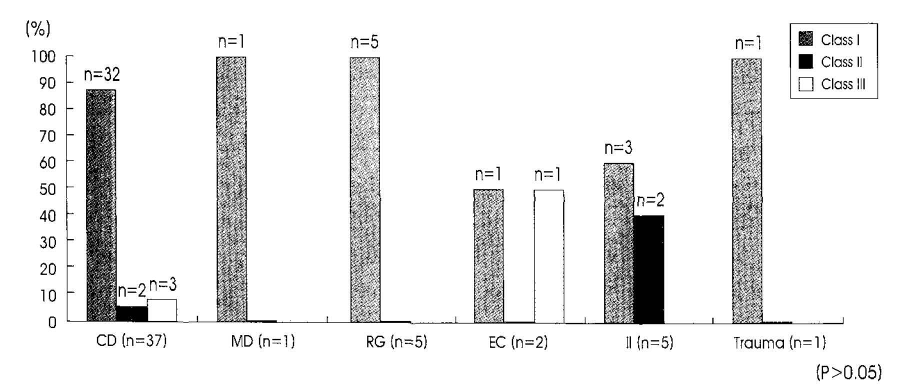
*CPS : complex partial seizure, SSMA Sz : supplementary sensorimotor area seizure, SPS : simple partial seizure

Fig. 4. Seizure outcomes analysis in terms of semiologic findings in ETLE patients (n=63).

class III in 1 (4%). Of 11 patients who had diffuse ictal EEG onset, Engel's class I was observed in 4 (36%) patients, class II in 3 (28%), and class III in 4 (36%). Consequently, patients with focal or regional ictal EEG onset had more favorable seizure outcome than those with diffuse ictal EEG onset, and there was definitely statistical significance between them ($P<0.05$).

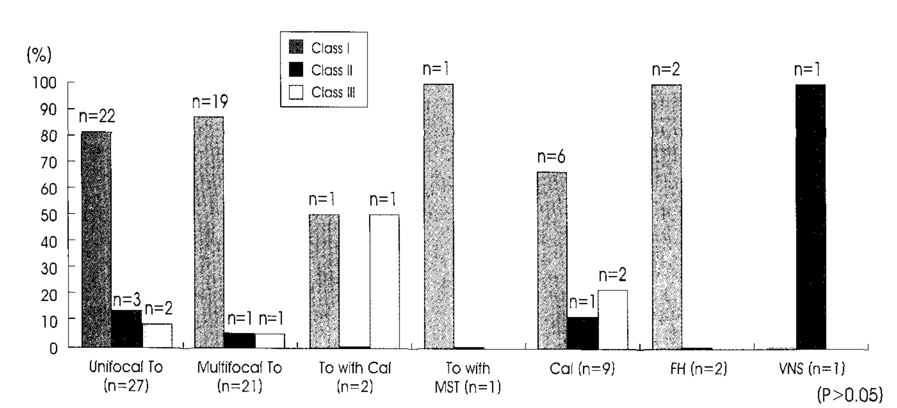
Seizure outcomes were analyzed in terms of semiology (Fig. 4). Of 46 patients who showed CPS, Engel's class I was observed in 36 (78%) patients, class II in 6 (13%), and class III in 4 (9%). Of 14 patients who showed SSMA seizure, Engel's class I was observed in 12 (86%) patients, and class III in 2 (14%). Of 3 patients who showed drop attack and SPS, Engel's class I was observed in all patients. Consequently, there was no statistical significance between semiologic findings and seizure outcomes ($P>0.05$).

Seizure outcomes were analyzed in terms of histopathological findings of topectomy specimens (Fig. 5). Of 38 patients with confirmed CD, Engel's class I was observed in 33 (87%) patients, class II in 2 (5%), and class III in 3 (8%). Five patients with low grade CD (CD occult and CD1) revealed Engel's class I, however, of 33 patients with relatively high grade CD (CD2 and CD3), Engel's class I was observed in 28 patients, class II in 2, class III in 3. Patients with relatively high grade CD showed more poor seizure outcome than those with low grade CD, but there was no statistically significant difference between them ($P>0.05$). Patients with reactive gliosis and traumatic lesion showed Engel's class I in all patient. Of 5 patients with ischemic insult histopathological findings, Engel's class I was observed in 3 (60%) patients, and class II in 2 (40%), and of 2 patients with encephalitis histopathological findings, Engel's class I was observed in 1 (50%) patient, and class III in 1 (50%). Consequently, there was no statistical significance between histopathological



*CD : cortical dysplasia, MD : microdysgenesis, RG : reactive gliosis, EC : encephalitis, II : ischemic insult

Fig. 5. Seizure outcomes analysis in terms of histopathological findings of topectomy specimen in ETLE patients (n=51).



*To : topectomy, Cal : corpus callosotomy, MST : multiple subpial transection, FH : functional hemispherectomy, VNS : vagus nerve stimulation

Fig. 6. Seizure outcomes analysis in terms of surgical procedures in ETLE patients (n=63).

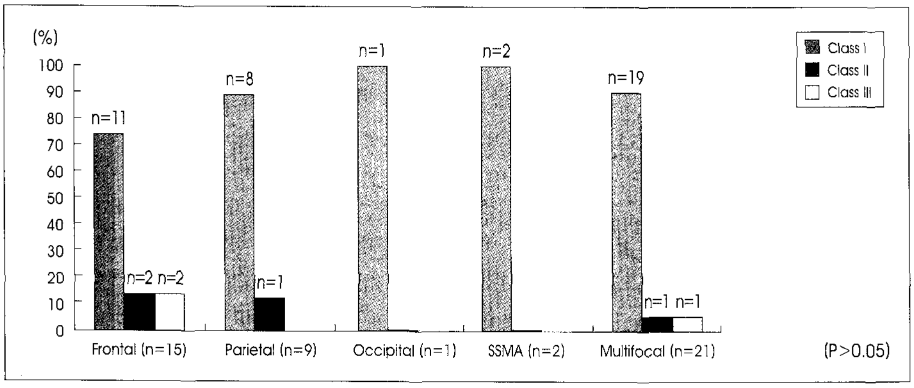


Fig. 7. Seizure outcomes analysis in terms of topectomy sites in ETLE patients (n=48).

findings and seizure outcomes (P >0.05).

Seizure outcomes were analyzed in terms of surgical procedures (Fig. 6). Of 27 patients undergoing unifocal topectomy, Engel's class I was observed in 22 (82%) patients, class II in 3 (11%), and class III in 2 (7%). Of 21 patients undergoing multifocal topectomy, Engel's class I was observed in 19 (90%) patients, class II in 1 (5%), and class III in 1 (5%). Of 9 patients undergoing corpus callosotomy, Engel's class I was observed in 6 (67%) patients, class II in 1 (11%), and class III in 2 (22%). Of 2 patients undergoing topectomy with corpus callosotomy, Engel's class I was observed in 1 (50%) patients, and class III in 1 (50%). In all patients undergoing surgical procedures including topectomy with MST, and functional hemispherectomy, Engel's class I was observed, but, in 1 patient undergoing VNS, Engel's class II was observed. Consequently, there was no statistical significance between surgical procedures and seizure outcomes (P > 0.05).

Seizure outcomes were analyzed in terms of topectomy sites (Fig. 7). Of 15 patients undergoing frontal lobe topectomy, Engel's class I was observed in 11 (74%) patients, class II in 2 (13%), and class III in 2 (13%). Of 9 patients undergoing parietal lobe topectomy, Engel's class I was observed in 8 (89%) patients, class II in 1 (11%). Of 21 patients undergoing multifocal topectomy, Engel's class I was observed in 19 (90%) patients, class II in 1 (5%), and class III in 1 (5%). Three patients undergoing occipital lobe or SSMA topectomy revealed Engel's class I. Consequently, there was no statistical significance between topectomy sites and seizure outcomes (P > 0.05).

Discussion

The objectives of this study were to analyze the seizure outcomes of patients with ETLE and to evaluate the relationship between seizure outcomes and prognostic factors in terms of preoperative evaluation modalities, surgical procedures, topectomy sites, and histopathological findings.

This study shows that surgery is an effective treatment modality for intractable ETLE as well as intractable TLE.

Previous studies have indicated that patients with ETLE have poorer seizure outcome than those with TLE. Siegel et al.[19] reported that in 75 patients who were operated on for frontal lobe epilepsy, 64% were postsurgically seizure-free, 12% had only rare seizures, 16% showed a significant reduction in seizure frequency, and 12% showed no significant reduction. Drzezga et al.[5] reported that after temporal lobe resection, 70% of patients with TLE were seizure-free, whereas approximately 45% of patients with ETLE were seizure-free postoperatively. However, our result demonstrated that 80% of patients with intractable ETLE were seizure-free after operation. This result suggests a very high successful rate compared with other previous studies.

Antiepileptic drugs are usually considered to be the first therapeutic modality. However, less than 33% of all patients achieve full control of seizures after 1 year on monotherapy, and only 10-20% of the failures achieve full control of seizures even with two-drug therapy[19]. Interestingly, the percentage of drug-resistant epilepsies has not diminished significantly, in spite of recently introduce antiepileptic drugs. Previous investigators suggested that surgery is the most effective treatment for intractable ETLE. Cascino[2] has demonstrated that the most effective treatment for intractable ETLE is focal cortical resection with excision of the epileptic zone. Shukla et al.[17] reported a good surgical outcome in 87% of intractable ETLE patients. Zentner et al.[21] found that good outcome was observed in 68.3% of patients who were operated on for intractable ETLE, while a total of 86% of patients showed some benefit with surgery. These studies support our operative results suggesting that surgery is an effective therapeutic method for ETLE.

In this study, we evaluated seizure outcomes and prognostic factors affecting seizure outcome. We acquired a good surgical outcome of ETLE patients compared with other previous studies. We believe that our good results are attributed to visualization of lesions on multimodal neuroimaging study (MRI, 3D-surface rendering), and confirmation of epileptogenic zone using EEG findings and semiology.

Mihara et al.[13] demonstrated that of patients with no MRI-detectable lesions who underwent ETLE surgery, less than 50% had a seizure outcome of Engel's class I and II. Hosking et al.[9] have reported that the presence of a single MRI-identified abnormality is one of the most accurate presurgical predictors of seizure-free outcome. Cascino et al.[3] have suggested that neuroimaging-identified lesions and foreign tissue pathology are favorable prognostic factors for seizure outcome in ETLE. Schramm et al.[15] have reported that the presence of lesions on neuroimaging study is a prognostic factor for a better outcome. Siegel et al.[18] have reported that patients with MRI abnormalities have more favorable outcome than those with normal MRI. Our study also showed statistical significance with neuroimaging abnormalities. However, in this study, we used not only conventional MRI, but also 3D-surface rendering with MRI to find structural abnormality. We thought that this combined neuroimaging workup would lead a good seizure outcome. Initially, 20 (32%) of 63 patients had no structural abnormalities on MRI excluding tumors and vascular lesions. After 3D-surface rendering with MRI, out of our 20 patients with normal MRI, 13 patients revealed abnormal gyration.

Chronic video-EEG monitoring not only allow adequate observation of seizure, but also enables the lateralization and localization of epileptogenic focus. Effective surgical treatment of patients with intractable ETLE is dependent upon accurate localization of the epileptic focus and precise delineation of the epileptogenic region[2,7]. However, Siegel[19] has reported that in frontal lobe epilepsy, abnormal EEG patterns in surface EEG could be observed in only about 10% of patients. Consequently, the ictal EEG recording with chronically implanted subdural or depth electrode and intraoperative ECoG is also required in ETLE. Cascino et al.[3] have report that the use of extraoperative or intraoperative functional mapping in patients with ETLE improves neurologic outcome. Holmes et al.[8] have reported that a unilateral, unifocal epileptiform EEG pattern is a favorable prognostic factor in refractory ETLE patients. In this study, we performed invasive EEG monitoring with SDG, and intraoperative functional mapping to delineate the ictal onset zone, and reduce the neurologic morbidity. We obtained a good seizure outcome in patients with focal or regional ictal EEG onset zone. In this study, semiology and seizure outcomes did not related statistically. However, semiology provided the clue of epileptogenic focus. The meticulous analysis of semiology is important as well as neuroimaging study. In patients with non-structural abnormality, only semiology suggested the epileptogenic zone.

Functional neuroimaging studies such as SPECT and PET can be helpful in presurgical diagnostic workup of medically intractable epilepsy. However, in ETLE, their diagnostic value has been reported to be lower than in TLE. It has generally been known that ETLE is infrequently associated with focal hypometabolism in PET unlike TLE[2,5,10]. Drzezga et al.[5] found that in ETLE, the accuracy of interictal PET was significantly lower (45% or less) depending on the localization of the focus. Interictal SPECT also showed a low diagnostic yield in patients with ETLE[2]. The low diagnostic accuracy of PET and other diagnostic modalities may explain why few patients with ETLE undergo surgical treatment and also why postoperative results are often unsatisfactory. On the other hand, ictal SPECT can be performed in patients with ETLE and expected to potentially provide information on the localization or lateralization of epileptogenic zone[2,7,10]. Lee et al.[11] have reported that a good surgical outcome is correlated with the presence of focal interictal spikes, focal hypometabolism on FDG-PET, and concordance of presurgical evaluation. In this stidy, we observed a low diagnostic sensitivity of interictal PET (43%) and subtraction of ictal/interictal difference of SPECT (23%). PET and SPECT were not helpful in the assessment of lateraliztion and localization of epileptogenic zones in our ETLE patients.

The current primary surgical treatment of ETLE is partial resection of frontal, parietal or occipital lobes, which is limited to the epileptogenic focus[2,19]. Award et al.[1] have suggested that in cases where complete resection is not feasible, a favorable outcome can still be achieved with carefully planned subtotal resection of lesions of foci. Siegel[19] reported that in 75 patients who were operated on for frontal lobe epilepsy, 64% were postsurgically seizure-free, in 39 patients undergoing parietal lobe epilepsy surgery, 52% were postsurgically seizure-free, in 30 patients undergoing occipital lobe epilepsy surgery, 71% were seizure-free. Guenot[6] reported that an average of 60% of patients with frontal lobe epilepsy were seizure-free after surgery in adult as well as in children. Holmes[8] reported that in 126 patients who were operated on for intractable ETLE, 43% were postsurgically seizure-free. Our results showed a more favorable seizure outcome than other previous studies. In 15 patients with frontal lobe topectomy, 74% were seizure-free, in 9 patients with parietal lobe topectomy, 89% were seizure-free, in 1 patient with occipital lobe topectomy and 2 patients with SSMA topectomy, all were seizure-free, and in 21 patients with multifocal topectomy, 90% were seizure-free. Frontal lobe epilepsy yielded the worst postoperative seizure outcome in this study. However, correlation with topectomy sites and seizure outcome did not show statistical significance.

Although surgical approaches showed no statistical significance with seizure outcome, we compared our results with other prior studies. Callosotomy is probably one of the best palliative operations for intractable ETLE. In seizure type, status epilepticus and drop attacks respond especially well to callosotomy[6,16,19]. Seo et al.[16] reported that of 36 patients who had intractable drop attacks, 22 (61%) patients had satisfactory surgical outcome after callosotomy. Guenot et al.[6] reported that 65% to 85% of patients with medically intractable epilepsy achieved a significant reduction in overall seizure frequency after surgery. In this study, callosotomy was performed in 9 patients with drop attack and diffuse ictal EEG onset. Two patients with drop attack were all seizure-free. Of 7 patients with diffuse ictal EEG onset, Engel's class I was observed in 4 patients, class II in 1, and class III in 2. Consequently, of 9 patients underwent callosotomy, 6 patients (67%) were seizure-free, which revealed a more favorable outcome than other previous studies. Functional hemispherectomy is a surgical procedure where a cerebral hemisphere is either anatomically removed or made nonfunctional by disconnection, which is usually performed in the pediatric population. Siegel[19] reorted that of 68 patients with hemispherectomy, 80% of patients were postsurgically seizure-free. Guenot et al.[6] reported that average of 60% of patients were seizure-free after hemispherectomy. We performed functional hemispherectomy in 2 pediatric patients, and these patients were seizure-free. MST is a relatively new palliative surgical technique which was developed for medically refractory partial epilepsy originating from an eloquent region such as speech area or motor/sensory cortex[9,19,21]. MST can also be combined with cortical resection. Siegel[19] reported that of 100 patients with MST, 48% were postsurgically seizure-free. We performed MST combined with frontal lobe topectomy in 1 patient with an epileptogenic lesion in the primary motor cortex, who revealed Engel's class I outcome. VNS is indicated for patients with medically refractory partial epilepsy who are not good candidates for resective surgery[11,19]. VNS may be an alternative method for patients with no change in seizure control after callosotomy[16,19]. We performed VNS in 1 patient with an epileptogenic lesion in Wernicke's area, who revealed Engel's class II outcome.

Kim et al.[10] have suggested that the severity of cortical dysplasia is correlated with surgical outcome. On the other hand, Chung et al.[4] have proposed the severity of cortical dysplasia and frontal lobe resection as independent prognostic factors for worse outcome, and they showed worse postoperative seizure outcome in cases with mild CD. However, this study showed that patients with relatively high grade CD showed worse seizure outcome than those with low grade CD, but there was no statistically significant difference between them ($P>0.05$).

Consequently, presence of structural abnormalities on neuroimaging study (MRI and 3D-surface rendering with MRI), and focal or regional ictal EEG onset seem to be related to favorable seizure outcome, and there was definitely statistical significance ($P<0.05$). The other factors (semiology, histopathology, surgical procedures and topectomy sites) showed no statistical significance. These results suggest that presence of structural abnormalities on neuroimaging study, and focal or regional ictal EEG onset were favorable prognostic factors in ETLE surgery. Also, we assumed that considerate patient selection, accurate identification of epileptogenic foci, and appropriate surgical techniques may lead to a more favorable seizure outcome in ETLE patients. Further studies with a long-term follow-up of a large series of cases are needed to validate this assumption.

Conclusion

A good seizure outcomes were affined in patients with intractable ETLE. Presence of structural abnormalities on neuroimaging study and focal or regional ictal EEG onset could lead to more favorable seizure outcome in ETLE patients. Also, the other factors related to favorable seizure outcome are considered as accurate identification of epileptogenic foci, considerate patient selection, and appropriate surgical techniques.

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Commentary

This paper dealt with surgical outcome of extratemporal lobe epilepsy, which has been reported as not well as that of temporal lobe epilepsy. The authors achieved 80% of seizure-free outcome, which is the highest one, as I know. Also there was no Engel class IV outcome in their series. For the analysis of prognostic factors, they said that neuroimaging abnormality and focal or regional ictal onset are important ones. Considering current preoperative investigation protocols, their protocol was very unique, because they did use PET or ictal SPECT in only a fraction (44/63, 7/63 respectively).

One of the important things in surgery for extratemporal lobe epilepsy is how to determine the resection area. Authors described their surgical methods in detail at Surgery and Histopathology section. However, I could not guess how they defined the resection area in "patients who had diffuse bilateral ictal EEG onset". The authors emphasized the importance of the structural abnormalities. They resected cortices having abnormal consistency in diffuse ictal EEG onset. However, I could not guess how many patients had abnormal cortical consistency and how many not. I am still wondering how the authors treat a patient having diffuse ictal EEG onset and no abnormal cortical consistency.

As I told in the first paragraph, the authors' result was the best in literatures having more than 50 cases as I know. I think one of the reasons how they achieved this kind of excellent result was that most of their patients had some kinds of structural abnormality (43/63, 56/63 if 3D surface rendering considered). We, epilepsy surgeons, are well aware that regardless of lobar location the patients having structural abnormality are expected to have a good surgical outcome.

Even though this paper has some limitations, I would like to commend the authors for their excellent results. However, in this paper they have not provided convincing explanations how they had achieved it. I hope this paper would be a base to provide a more plausible explanation.

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