Longitudinal Change in Outcome of Frontal Lobe Epilepsy Surgery

**BACKGROUND:** Although the outcome of epilepsy surgery changes with time, few studies have considered longitudinal changes after frontal lobe epilepsy (FLE) surgery.

**OBJECTIVE:** To assess the longitudinal changes after FLE surgery.

**METHODS:** Resection of the seizure onset zone was performed in 76 patients with FLE. Invasive monitoring was performed in 56 of these 76. Awake craniotomy was performed in 43 of the 76 patients. More than 50% of patients were followed up for at least 7 years. The mean follow-up was 81 months.

**RESULTS:** For all patients, the seizure-free rate was 79% at 6 months, 64% at 1 year, 55% at 2 years, and 55% at 7 years. For patients with cortical dysplasia, the seizure-free rate was 72% at 6 months, 53% at 1 year, 51% at 2 years, and 46% at 7 years. For patients with tumor, the seizure-free rate was 89% at 6 months, 83% at 1 year, 83% at 2 years, and 74% at 7 years. Patients with tumor showed better outcome than those with cortical dysplasia ($P = .04$). Although the overall seizure-free rate became stable after 2 years, individual status changed for up to 5 years. Seizures recurred in 11 patients within 1 year (early recurrence) and in 12 patients by 1 to 5 years (late recurrence). Antiepileptic drug (AED) medication was adjusted in all patients with recurrence. Patients with late recurrence had a more favorable response (Engel class I or II) than early recurrence ($P < .01$).

**CONCLUSION:** The overall seizure outcome changes mostly during the first year. However, individual seizure status changes for up to 5 years. The outcome of late recurrence is favorable to AED adjustment.

**KEY WORDS:** Epilepsy, Frontal lobe, Longitudinal study, Magnetic resonance imaging, Surgery

Frontal lobe epilepsy (FLE) is the second most common localization-related epilepsy, after temporal lobe epilepsy. However, seizure outcome after FLE surgery is relatively poor. Determining the localization of the seizure onset zone is difficult, because of varying etiologies, widespread seizure onset zone, and rapid spread of ictal rhythm. Moreover, the nearby presence of eloquent areas hinders complete resection of the seizure onset zone. In general, studies on outcome of epilepsy surgery have used cross-sectional analyses. Although the outcome of epilepsy surgery changes with time, few studies have considered longitudinal changes after FLE surgery.

We previously published a cross-sectional outcome analysis of FLE surgery that did not address chronological changes. Here, we present the longitudinal/chronological changes in the outcome of FLE surgery and identify prognostic factors for this type of surgery.

**SUBJECTS AND METHODS**

We retrospectively reviewed 76 patients (aged $\geq 18$ years) who were diagnosed with FLE and underwent frontal lobe resection between 1994 and 2006. Inclusion criteria were resection restricted to the frontal lobe and a follow-up period $\geq 24$ months. Patient characteristics are listed in Table 1. Complex partial seizure was the most common type of seizure.
TABLE 1. Patient Characteristics

| Category/No. | Total (76) | Cortical Dysplasia (43) | Tumor (18) | Others a (15) |
|--------------|------------|-------------------------|------------|---------------|
| Male:female  | 47:29      | 30:13                   | 10:8       | 7:8           |
| Age, y       | 28.5 ± 9.3 | 26.2 ± 5.7              | 31.8 ± 10.4| 31.1 ± 14.0   |
| Onset age, y | 16.0 ± 12.4| 10.1 ± 5.9              | 25.0 ± 13.6| 21.8 ± 15.7   |
| Duration of seizures, y | 12.5 ± 7.8   | 16.1 ± 6.9              | 6.7 ± 6.3  | 9.2 ± 6.4     |
| Frequency of seizure/mo | 9.0 ± 19.9   | 12.6 ± 25.2             | 4.4 ± 7.3  | 5.0 ± 7.6     |
| Past medical history | 12          | 6                       | 6          |
| Trauma       | 6          | 3                       | 3          |
| Encephalitis | 3          | 2                       | 2          |
| Near drowning| 2          | 2                       | 2          |
| Developmental delay | 1       | 1                       | 1          |
| Febrile convulsion | 12      | 10                      | 2          |
| Neurological deficit | 56       | 43                      | 11         |
| Invasive study | 43         | 19                      | 13         | 11            |
| Awake surgery | 43         | 19                      | 13         | 11            |
| Follow-up, mean, mo | 81.3 ± 34.4 | 92.9 ± 31.5             | 67.3 ± 36.0| 64.7 ± 28.9   |

aIncludes 5 vascular lesions and 10 miscellaneous lesions.

(57%, 43/76 patients), followed by simple partial seizure (43%, 33/76 patients). The seizure was secondarily generalized in 59% (45/76) of patients. The seizure onset zone was on the right frontal lobe in 49% (37/76) of patients and on the left in 51% (39/76) of patients. Diagnosti
c work-ups included routine history taking, physical and neuro
ological examinations, prolonged interictal electroencephalography (EEG), video-EEG monitoring (V-EEG), MRI, 18F-fluorodeoxyglucose positron emission tomography (PET), and interictal and ictal Tc-99m hexamethyl-propylene-amineoxime single-photon emission computed
tomography (SPECT).

EEG, V-EEG, MRI, and PET were routinely obtained whenever possible. V-EEG was not routinely performed in cases presenting with a
tumorous lesion with a distinct margin, as assessed by MRI, and for
those who results of EEG, the semiology of the seizure, or other studies
were congruent. Intertical and ictal SPECT were performed if necessary,
especially in cases with uncertain localization or localization of the
seizure onset zone. Localization of the seizure onset zone was decided when the predominant abnormality was confined to the frontal lobe, as
assessed by interictal EEG, V-EEG, MRI, PET, interictal SPECT, or ictal SPECT. The results of 6 work-ups were classified as either locali
zation or no localization. The mean follow-up period was 81.3 ± 34.4
months. More than 50% of patients (41/76) were followed up for at least
7 years. The pathological diagnosis of cortical dysplasia was performed according to the classification suggested by Palmini et al and included mild
malformations caused by abnormal cortical development (MCD) and focal cortical dysplasia (FCD) types IA, IB, IIA, and IIB. This study
was approved by the Institutional Review Board of the Seoul National
University Hospital (H-0805-055-245).

Operation

Lesionectomy was performed without an invasive study in cases where
MRI, EEG, or other imaging methods (eg, PET) congruently detected the
presence of a distinct lesion (26%, 20/76 patients). Subdural electrodes
were placed (making it an invasive study) if the lesion was not apparent on
MRI, if the margin of the lesion was ambiguous, or if the presumptive
seizure onset zone overlapped with the eloquent area. After invasive study,
video-electrocorticographic monitoring was performed until at least
3 typical seizures occurred. A second invasive study was immediately
performed in cases where ictal activity occurred from the partially sampled
area, where there was simultaneous or independent onset in 2 separate
areas, or where onset occurred in the distal end of the electrode strip or grid.
The seizure onset zone could be localized following the second invasive
study in 9 patients. Overall, an invasive study was necessary in 74% (56/76). Functional brain mapping was performed after delineation of the
seizure onset zone. Awake craniotomy was performed under local anes
thesia for intraoperative functional brain mapping in cases where the
eloquent area was near the seizure onset zone (57%, 43/76). We tried to
remove all visible lesion tissue and the seizure onset zone, which was
confirmed by video-electrocorticographic monitoring. Resection using
subpial dissection was limited by sulci. Crossing vascular structures were
preserved as much as possible. Intraoperative mapping was performed
intermittently to ensure the functional cortex was preserved.

Pathological examination was performed in all patients (Table 2). Cortical
dysplasia was the most common pathology (57%, 43/76).

Awake Craniotomy

A scalp nerve block was performed on the supraorbital, supratrochlear,
auriculotemporal, and lesser and greater occipital nerves on the surgical
side using 0.25% bupivacaine containing 1:200 000 epinephrine. The
incision site was infiltrated with the same local anesthetics. Oxygen was
administered via a nasal cannula. Intra-arterial blood pressure, end-tidal
CO2, and respiratory rate were monitored throughout the operation, and
arterial blood gas analysis was performed intermittently. No sedative
agents were used until the cortical mapping was completed, to avoid
hindering the functional mapping by patient confusion. Fentanyl citrate
and propofol (if necessary) were infused after successful completion of the
cortical mapping.

Outcome Classification

Outcome was classified using Engel’s seizure outcome scale. Engel
class I included seizure-free status, auras only, or seizure restricted to the
first postoperative week. Cases where a seizure occurred once because of
the abrupt discontinuation of an antiepileptic drug (AED) against the



**TABLE 2. Results of the Pathological Examination (n = 76)***

| Pathology          | No. patients |
|--------------------|--------------|
| Cortical dysplasia (43) | 5            |
|      FCD IA      | 24           |
|      FCD IB      | 7            |
|      FCD IIA     | 3            |
|      FCD III     | 4            |
| Tumor (18)        |              |
|      Anaplastic astrocytoma | 3          |
|      Anaplastic ganglioglioma | 1          |
|      Anaplastic oligodendroglioma | 1         |
|      Astrocytoma  | 2            |
|      Oligodendroglioma | 4          |
|      Oligoastrocytoma | 1           |
|      Pleomorphic xanthoastrocytoma | 2         |
|      Dysembryoplastic neuroepithelial tumor | 2         |
| Vascular (5)      |              |
|      Cavernous angiomato | 3           |
| Miscellaneous (10)|              |
|      Arteriovenous malformation | 2          |
|      Cortical scar | 5            |
|      Cerebromalacia | 2            |
|      Fibrous nodule | 1            |
|      Heterotopia  | 1            |
|      Tuberous sclerosis | 1          |

*FCD, focal cortical dysplasia; MCD, malformations caused by abnormalities of cortical development.  †Palmini’s classification.

Patients were classified as Engel class II if seizures occurred very rarely. As suggested by Engel, class II was somewhat subjective. We considered the degree of disability of each seizure in class II; when seizure caused disability, then frequency was less than once or twice per year, and when seizure was minimal, then frequency was less than 3 times per year. Patients were classified as Engel class III if there was a worthwhile improvement of seizures (>90% improvement in seizure frequency and intensity) and as Engel class IV if there was no improvement. Seizure recurrence was defined as the occurrence of a seizure after a seizure-free period of at least 6 months. The recurrence of seizures between >6 months to 1 year or >1 year after the operation were considered as early or late recurrence, respectively. Final seizure outcome status was determined by assessing the patient’s most recent 2 years of follow-up.

Statistical Analyses

We divided patients into three groups: cortical dysplasia (43), tumor (18), or others (15-5 vascular diseases and 10 miscellaneous lesions). Univariate and multivariate analysis were performed for all patients (n = 76) and for cortical dysplasia only (n = 43). However, small numbers hindered the analyses for tumor (n = 18) and others (n = 15). Instead, we provided longitudinal data for each group. The Kaplan-Meier survival analysis was used to estimate longitudinal seizure-free outcome (Engel class I for the most recent 2 years of follow-up). Cox logistic regression analysis was used to evaluate the hazard ratios (HR) and the 95% confidence interval (CI) for each risk factor and to perform multivariate analyses. A χ² test was used to compare noncontinuous values. The Mann-Whitney U test was used to compare nonparametric values. Two-sided P values < .05 were considered significant. All statistical analyses were performed using the commercially available SPSS software, version 12.0 (SPSS Inc., Chicago, Illinois).

**RESULTS**

**Overall Outcome**

Forty-two patients had a seizure-free outcome (Engel class I) at the last follow-up (mean 81.3 ± 34.4 months). Overall, the seizure-free rate was 79% at 6 months, 64% at 1 year, 55% at 2 years, and 55% at 7 years (Table 3 and Figure 1). To look at the difference in pathology, we performed subgroup analysis. For patients with cortical dysplasia, the seizure-free rate was 72% at 6 months, 53% at 1 year, 51% at 2 years, and 46% at 7 years (Table 3 and Figure 1). For patients with tumor, the seizure-free rate was 89% at 6 months, 83% at 1 year, 83% at 2 years, and 74% at 7 years (Table 3 and Figure 1). Patients with tumor showed better seizure-free outcome than patients with cortical dysplasia (P = .04, Kaplan-Meier survival analysis). The overall seizure-free rate became stable after 2 years, but individual outcome status changed up to 5 years after the operation in about 5% of patients (Figure 2). Sixty patients (79%) were under AED medication at last follow-up. There was no mortality and 1 permanent postoperative right hemiparesis (motor grade IV/V).

**Recurrence of Seizures**

Seizures persisted in 16 (21%) patients within 6 months of the operation. Recurrence was defined as a seizure that occurred after a seizure-free period of at least 6 months. Eleven patients had early recurrence (Figure 2). Although we recommended electrophysiological monitoring followed by repeat surgery, most patients refused this because they were satisfied with the improved seizure status. Seizures recurred in 7 patients during the second year after surgery (Figure 2). After 2 years, the changes in outcome became less dynamic, and seizures recurred in 5 patients over the following 3 years. Overall, 12 patients had late recurrence (Figure 2). A run-down phenomenon (ie, decrease in seizure frequency and intensity with time) was observed in 7 patients (Figure 2). After 5 years, there were no changes in individual seizure status.

**TABLE 3. Seizure-Free Rate Over Time**

| Time | Total (%) | Cortical dysplasia | Tumor | Others* |
|------|-----------|------------------|------|--------|
| 6 mo | 79        | 72               | 89   | 87     |
| 1 y  | 64        | 53               | 83   | 73     |
| 2 y  | 55        | 51               | 83   | 53     |
| 3 y  | 55        | 49               | 83   | 53     |
| 4 y  | 55        | 46               | 83   | 53     |
| 5 y  | 55        | 46               | 83   | 53     |
| 6 y  | 55        | 46               | 83   | 53     |
| 7 y  | 55        | 46               | 83   | 53     |

*Includes 5 vascular lesions and 10 miscellaneous lesions.
Early recurrences occurred in 11 patients at 7.8 ± 1.8 months and late recurrences occurred in 12 patients at 31.9 ± 23.6 months. Their outcome is described in Table 4. The precipitating events of late recurrence varied and included AED dose decrease (5 patients), fatigue (2 patients), intake of coffee (1 patient), and tumor regrowth (1 patient). There was no precipitating event in 3 patients. Patients with late recurrence had a more favorable outcome (Engel class I or II) compared with patients with early recurrence ($P < .01$, $\chi^2$ test) after AED change or resumption, with the exception of 1 patient with tumor recurrence who underwent tumor resection again, and finally obtained an Engel class I outcome 3 years after repeat operation.

Prognostic Factors

The patients’ characteristics did not correlate with seizure-free outcome ($P > .05$, Cox logistic regression analysis, Table 5). Assessment of the localization of the seizure onset zone (using V-EEG, MRI, and PET) and pathology (tumor vs non-tumor) as potential prognostic factors using multivariate analysis revealed that the localization of the epileptogenic zone by MRI ($P = .02$, corrected HR, 0.16; 95% CI, 0.04-0.71, Cox logistic regression analysis) and V-EEG ($P = .04$; corrected hazard ratio, 0.32; 95% CI, 0.11-0.94, Table 6) was significantly correlated with a seizure-free outcome. MRI-based localization of the epileptogenic zone was associated with a seizure-free rate of 88% at 6 months, 79% at 1 year, 74% at 2 years, and 62% at 4 years.

FIGURE 1. Seizure-free outcome over time. Kaplan-Meier plot shows the outcome of surgery for frontal lobe epilepsy according to pathology over time. The mean follow-up time was 81 months. CD, cortical dysplasia.

FIGURE 2. Change in FLE surgical outcome over time according to pathologies: cortical dysplasia (A); tumor (B); others (C). The category “others” includes 5 vascular lesions and 10 miscellaneous lesions. The numbers of seizure-free patients are illustrated according to time. The bold numbers and arrows in the figures indicate changes in seizure outcome, most of which present within 2 years after surgery. However, individual seizure outcome changed up to 5 years after operation. Overall, there were 11 cases of early recurrence (within 1 year after the operation) and 12 cases of late recurrence. A run-down phenomenon was observed in 7 cases.
years, and 70% at 5 years. V-EEG based localization of the epileptic zone was associated with a seizure-free rate of 68% at 6 months, 49% at 1 year, 43% at 2 years, and 40% at 5 years. Seizure outcome was stable thereafter.

Among the patients with cortical dysplasia (43/76), FCD type IIA and IIB cases exhibited a trend for a better prognosis compared with mild MCD or FCD type IA and IB cases \((P = 0.08, HR, 6.07; 95\% CI 0.82-45.12; Cox logistic regression analysis, Table 5)\). Localization of the epileptic zone with MRI was the only significant prognostic factor, and the result was the same in multivariate analysis \((P = 0.04; corrected HR, 0.22; 95\% CI, 0.05-0.94, Table 5)\).

**DISCUSSION**

Although the outcome of epilepsy surgery changes with time, \(^1\-6,8,13-17\) most previous reports used cross-sectional analyses, including our previous report. \(^5\) Chronological changes in surgical outcome are well documented in medial TLE, so overall and individual seizure statuses become stable 2 years after surgery. \(^10\) This information is crucial for the management of patients, especially in a drug modification plan setting. \(^18\) However, the data available for FLE surgical

| TABLE 4. Seizure Status After Recurrence |
|------------------|------------------|------------------|------------------|------------------|
|                  | Recurrence No. | Class I | Class II | Class III | Class IV |
| Total            | Early           | 11      | 2        | 1        | 6        | 2        |
|                  | Late            | 12      | 4        | 7        | 1        |
| Cortical dysplasia | Early          | 8       | 2        | 1        | 4        | 1        |
|                  | Late            | 8       | 4        | 4        |           |
| Tumor            | Early           | 1       | 1        |          |          |          |
| Others           | Early           | 2       | 1        | 1        |          |
|                  | Late            | 3       | 2        | 1        |          |

\(^*\)Includes 5 vascular lesions and 10 miscellaneous lesions.

| TABLE 5. Correlation Between Patient Characteristics and Postoperative Seizure-Free Outcome |
|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Characteristics of patients     | All \((n = 76)\) Univariate*     | Multi^b                         | Cortical dysplasias \((n = 43)\) Univariate* | Multi^b                         |
| Age\(^c\)                      | 0.75                            | 0.99                            | 0.28                            | 0.95                            |
| Sex                           | 0.79                            | 0.99                            | 0.77                            | 0.91                            |
| Onset age\(^d\)               | 0.66                            | 0.26                            | 0.46                            | 0.35                            |
| Duration of seizure\(^e\)     | 0.18                            | 0.95                            | 0.44                            | 0.59                            |
| Semiology\(^f\)               | 0.44                            | 0.59                            | 0.65                            | 0.59                            |
| Monthly seizure frequency\(^g\) | 0.89                            | 0.76                            | 0.93                            | 0.91                            |
| Total seizure number\(^h\)    | 0.65                            | 0.67                            | 0.65                            | 0.65                            |
| Past medical history\(^i\)    | 0.34                            | 0.90                            | 0.67                            | 0.90                            |
| History of febrile convulsion | 0.76                            | 0.91                            | 0.34                            | 0.90                            |
| Secondary generalization       | 0.43                            | 0.72                            | 0.65                            | 0.90                            |
| Sidedness (right vs left)      | 0.08                            | 0.15                            | 0.43                            | 0.72                            |
| Anesthesia method (general vs awake) | 0.08                           | 0.19                            | 0.08                            | 0.19                            |
| Pathology (cortical dysplasia vs others\(^j\)) | 0.08                           | 0.19                            | 0.08                            | 0.19                            |
| Pathology (tumor vs others\(^k\)) | 0.14                           | 0.15                            | 0.14                            | 0.15                            |
| Palmini's classification\(^l\) | 0.03                            | 0.11                            | 0.03                            | 0.11                            |
| EEG                           | 0.03                            | 0.11                            | 0.32 (0.11-0.94)                | 0.11                            |
| V-EEG                         | 0.03                            | 0.11                            | 0.02                            | 0.04                            |
| MRI                           | 0.003                           | 0.04                            | 0.02                            | 0.04                            |
| PET                           | 0.11                            | 0.37                            | 0.16 (0.04-0.71)                | 0.37                            |
| i-SPECT                       | 0.74                            | 0.94                            | 0.27                            | 0.51                            |
| ii-SPECT                      | 0.74                            | 0.94                            | 0.27                            | 0.51                            |

\(^*\)Cox logistic regression analysis was used.

\(^b\)Multivariate analysis using Cox logistic regression. Localization of the seizure onset zone using V-EEG, MRI, and PET and the severity of cortical dysplasia were assessed as potential prognostic factors using multivariate analysis (the bold \(P\) values in univariate analysis). Hazard ratios were marked below \(P\) values.

\(^c\)Data were analyzed as a continuous variable.

\(^d\)Complex partial seizure vs simple partial seizure.

\(^e\)Trauma; 6; encephalitis, 3; near drowning, 2; developmental delay, 1.

\(^f\)Other lesions included 18 tumors, 5 vascular lesions, and 10 miscellaneous lesions. Details are described in Table 2.

\(^g\)Other lesions include 43 cortical dysplasia, 5 vascular lesion, and 10 miscellaneous lesions. Details are described in Table 2.

\(^h\)Mild MCD and FDC IA and IB AQ: 9 form 1 group, whereas FCD IIA and IIB form the other group. These 2 groups were compared.
outcome are limited. In this article, we have described the chronological changes in seizure outcome in a relatively large group of patients. In the present study, 54% of patients were followed up for more than 7 years and the mean follow-up period was 81 months. We reviewed all pathological slides and classified cortical dysplasia as suggested by Palmini et al.3

Seizure Recurrence

The overall seizure outcome changed mostly within the first 2 years after surgery, which is in accordance with previous reports. However, there were 12 cases of late recurrence, which most commonly occurred in patients with cortical dysplasia. Most seizure recurrence occurred within 2 years after surgery, but individual seizure outcome changed in about 5% of patients up to 5 years after the operation. Jeha et al6 reported that recurrence happens mostly in the first 6 months, which is in contrast to our results. In their paper, the mean recurrence time was 2 months, whereas the early recurrence time in the present study was 7.8 months. The definition of recurrence in immediate postoperative time makes a difference. If seizures reappeared within 6 months after the operation, we considered that the seizure persisted. Recurrence was defined as a seizure that occurred after a seizure-free period of at least 6 months.

Patients with early recurrence showed a less favorable outcome compared with patients with late recurrence. There may be some differences in the mechanisms underlying early and late seizure recurrence. Surgical scar, disinhibition of a secondary epileptogenic lesion, residual lesion with low epileptogenic potential, or a residual primary epileptogenic lesion may underlie seizure recurrence. Identification of specific causes in individual patients would allow the development of better treatment modalities to correct the cause of recurrence. However, it is not possible to identify the cause of recurrence in every patient. In patients with early recurrence, the outcome following optimal AED medication was not satisfactory. We should probably consider surgical options with electrophysiological monitoring, even after apparent removal of the primary epileptogenic zone delineated by MRI or by invasive study.

About half of the patients with late recurrence had a history of AED tapering. Medications were adjusted individually, and most patients reached a favorable outcome. This finding is in accord with previous results and suggests that drug modification is a good strategy for patients with late seizure recurrence. Maintenance of a seizure-free status for 2 years may enable the discontinuation of AEDs in patients with TLE. However, the findings of the present study suggest that this strategy is not applicable to those with FLE. Our previous cross-sectional study did not address management strategies. Chronologic/longitudinal analyses suggest that patients undergoing surgery for FLE should be closely monitored postoperatively for at least 5 years, because about 5% of patients showed recurrence of seizures.

Prognostic Factors

Localization of the epileptogenic zone by MRI was a favorable prognostic factor, which is in agreement with previous results. There is a highly significant correlation between the MRI-based identification of the lesion and the seizure onset zone in FLE. The likelihood of achieving total resection of the epileptogenic lesion is high in the presence of a discrete lesion identified by MRI; thus, MRI is crucial. This may explain better seizure-free rates in patients with tumor than in patients with cortical dysplasia. In our study, the presence of a discrete lesion in the frontal lobe indicated a 7-year seizure-free rate of 70%. However, because cortical dysplasia is a common pathology in FLE and the usual extent of cortical dysplasia is much wider than MRI, the role of MRI may be limited in the determination of the extent of surgical resection. Further studies of the localization of the seizure onset zone are necessary, especially in cases where the lesion is extensive or cannot be visualized by MRI.

The importance of electrophysiological monitoring of seizures in epilepsy surgery has been emphasized. In this series, the
localization of the seizure onset zone by V-EEG was not a significant prognostic factor in patients with cortical dysplasia. In the absence of distinct lesions, the extent of resection could be determined from the results of video-electrocorticographic monitoring after invasive study. In this regard, V-EEG has limitation in determining the extent of resection. It could explain the high rate of invasive studies (video-electrocorticography, 100%, 43/43) for patients with cortical dysplasia observed in this study.

PET also seems to be a promising diagnostic tool, especially in cases of neocortical epilepsy with cortical dysplasia. Jeha et al suggested that their nonsignificant PET result in FLE surgery may be from a selection bias. In their study, PET was performed in 52% (37/70) of patients. In the present study, PET was performed in 82% (62/76) of patients and still was not a significant prognostic factor. Jeha et al’s results may not be due to selection bias, as they suggested. Our study indicates that PET may not have an independent predictive value in FLE surgery.

Ictal SPECT can identify the region with acute ictal hyperperfusion within the temporal lobe, which is known to be correlated with the epileptic zone. However, in other areas of the brain, this method is subject to locate the propagated zone, not the epileptic zone. Although ictal SPECT theoretically is a very good diagnostic method, the changeover to a postictal hyperperfusion state may occur very quickly in FLE. To obtain an exact ictal SPECT, the isotope should be injected at the time of seizure. Without an automated injector or standby medical personnel, this is difficult, and the results sometimes are misleading. That may explain the low diagnostic value of ictal SPECT observed in our study.

Types IIA and IIB FCD are characterized by truly abnormal, grossly dysmorphic cellular elements and exhibit good seizure outcome. In our series, severe FCD was a probable good prognostic factor in patients with cortical dysplasia, which correlates with previous reports. However, this result warrants further confirmation, given the small number of FCD IIA and B cases available in our study.

Limitations of This Study

This study had several limitations. First, complete diagnostic work-ups were not performed for all patients, which may lead to underestimation of the value of individual studies. In particular, V-EEG was performed in only 86% of patients, which may underestimate the value of this study. V-EEG was not a routine study for patients with distinct tumorous lesions detected by MRI. Secondly, the number of early and late recurrence cases was small, and we could not identify risk factors for recurrence. More cases should be recruited to address this issue. Thirdly, we tried to present prognostic factors for patients with cortical dysplasia; however, the small number of patients with severe FCD precluded the extraction of valuable information from these patients. Despite these limitations, this study is meaningful, because it identified long-term chronological changes in the surgical outcome of FLE surgery and suggested a possible treatment strategy, which may be helpful for the management of patients.

CONCLUSION

The overall seizure outcome of FLE surgery changes mostly during the first year after operation. However, individual seizure status changes up to 5 years after surgery, and close attention should be paid for at least 5 years. The outcome of surgery in patients with late recurrence is favorable to adjustment of AED.

Disclosure

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**COMMENT**

In this article, Kim et al report the results of a retrospective study regarding seizure outcome in frontal lobe epilepsy. They studied 76 patients with frontal lobe epilepsy who underwent surgical resection. This is a large study with a long follow-up period, and the authors should be commended for this work. The results of this longitudinal analysis in surgical patients with frontal lobe epilepsy are quite similar to the results already published by Jeha et al (*Brain*. 2007;130:574-584), who also studied seizure recurrence over a long period of time and in different pathological groups. Nevertheless, this well-written study will reinforce previous conclusions regarding postoperative changes in seizure frequency and severity in long periods of follow-up, stressing the need for long outcome periods to completely access the success of epilepsy surgery in frontal lobe seizures.

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