Lesionectomy versus electrophysiologically guided resection for temporal lobe tumors manifesting with complex partial seizures

Rashid Jooma
Aga Khan University, rashid.jooma@aku.edu

MICHAEL D. PRIVITERA
Mayfield Neurological Institute, Cincinnati, Ohio

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Lesionectomy versus electrophysiologically guided resection for temporal lobe tumors manifesting with complex partial seizures

RASHID JOOMA, M.D., F.R.C.S.Ed.(SN), HWA-SHAINYEH, M.D., MICHAEL D. PRIVITERA, M.D., AND MAUREEN GARTNER, R.N., M.Ed.

Departments of Neurosurgery and Neurology, University of Cincinnati College of Medicine, and Mayfield Neurological Institute, Cincinnati, Ohio; and Jinnah Post-Graduate Medical Center, Karachi, Pakistan

Complex partial seizures associated with tumors and other mass lesions are readily diagnosed by modern imaging techniques but their optimum surgical treatment remains unresolved. Lesionectomy has been reported to produce seizure outcomes equal to outcomes after resection that ablates the epileptogenic cortex with the lesion. However, some evidence suggests that when the lesion is in the temporal lobe, simple excision of the tumor or lesion more often fails to control seizures. After retrospectively reviewing the records of 30 patients with complex partial seizures and temporal lobe tumors who underwent surgical treatment at the University of Cincinnati hospitals (1985–1992), the authors divided them into two groups: Group A (16 patients) underwent lesionectomy only and Group B (14 patients) received surgical treatment for seizures with electroencephalographic delineation of the epileptogenic zone and resection of the lesion. Seizure control was best achieved in Group B patients with 13 (92.8%) seizure free at follow up (mean 52 months). Only three (18.8%) of the Group A patients became seizure free after lesionectomy at follow up (mean 33 months). In eight Group A patients, who underwent temporal lobectomy as a second procedure after lesionectomy failed to control seizures, five (62.5%) became seizure free. Group B patients had a longer duration of seizures and were more likely to have lesions smaller than 2.5 cm compared with Group A. Analysis of covariance demonstrated that the differences in outcome between the groups remained significant even with adjustment for the variation in duration of seizures (p = 0.0006) and size of tumor (p = 0.0001). Based on this study, the authors found that the probable relief from seizures caused by a temporal lobe lesion is greater if the region of epileptogenicity, usually the amygdalohippocampal complex, is resected along with the tumor in a temporal lobectomy.

Key Words • epilepsy • epilepsy surgery • lesionectomy • tumor

The widespread use of computer-based imaging methods in the early evaluation of patients with complex partial seizures has increased the frequency by which structural lesions are discovered prior to surgical treatment of epilepsy. Traditional wisdom, based largely on the Montreal Neurological Institute experience, holds that optimum seizure control is achieved when the lesion is removed with surrounding epileptogenic cortex as determined by intraoperative electrocorticographic (ECoG) study. Although some investigators have noted the importance of defining and extirpating the epileptogenic zone, others recently reported favorable experiences with lesionectomy. Overall, seizure control after lesionectomy has been comparable with that of traditional methods; lesionectomy using stereotactic techniques also holds the promise of reduced morbidity. However, when analyzed by location, the results of lesionectomy in the temporal lobe are disappointing; only two (22%) of the nine patients with lesions in this location became seizure free in the series reported by Cascino and colleagues. We hypothesized that when the epileptogenic lesion is close to the amygdalohippocampal complex and the perforant path, lesionectomy is less likely to control seizures than lesion-plus-epileptogenic-region resection. To test this hypothesis we conducted a retrospective study of two groups of patients with complex partial seizures and temporal lobe tumors treated by surgery: those who underwent lesionectomy and those treated by seizure surgery with electroencephalographic (EEG) mapping and resection of the epileptogenic zone along with the lesion.

Clinical Material and Methods

Patient Population

The diagnostic indices of the Mayfield Neurological Institute and the Departments of Neurosurgery at University
of Cincinnati Medical Center and Children’s Hospital Medical Center were searched from 1985, when our comprehensive epilepsy program (CEP) became operational, to 1992. Patient records with a diagnosis of complex partial seizure and temporal lobe lesion demonstrable on magnetic resonance (MR) imaging, which became available in 1986, were accessed. Three patients with cavernous angiomas were included; those with high-grade astrocytomas, simple cysts, and arteriovenous malformations were excluded. Patients whose only lesion was mesial temporal sclerosis, microdysgenesis, or neuronal heterotopia without a mass on MR imaging were also excluded.

Thirty patients were categorized by surgical history into two groups. Individuals assigned to Group A (16 patients) had undergone a lesionectomy. After the initial lesion-directed procedure failed to control seizures in eight of these patients, a second operation to treat the seizures was performed 2 months to 10 years later (mean 3 years). The second procedure, anterior temporal lobectomy, was implemented to treat seizures rather than lesion recurrence. Different surgeons operated on the Group A cases. Individuals assigned to Group B (14 patients) were managed by the Epilepsy Service and had interictal EEG, ictal video/EEG, and intraoperative EEG recordings to localize the epileptogenic regions for resection. Both groups were treated during the same time period but were operated on by different surgeons using different approaches.

Presurgical Evaluation
The complexity of the presurgical evaluation process varied depending on whether the evaluation was lesion directed or epileptogenic-region directed.

Neuroimaging. Magnetic resonance imaging was obtained in all patients. Computerized tomography (CT) scans were obtained regularly in the earlier patients and in some of those with suspected calcification shown on MR imaging in the recent past. Angiography was performed only as part of the intracarotid amobarbital procedure (IAP or Wada test) in 13 patients.

Electroencephalographic Recording. Patients evaluated in the CEP protocol underwent multiple EEG recordings with sphenoidal electrodes to sample interictal activity during both sleep and the resting state. Nine patients had no EEG study prior to surgery.

Prolonged Video–EEG Monitoring. All 14 patients in Group B were admitted to the epilepsy monitoring unit for prolonged video–EEG study. Anticonvulsant medications were reduced or stopped to capture at least three habitual seizures for which the behavioral and EEG events were analyzed for localizing features. Five Group A patients had video–EEG monitoring and two patients were monitored with implanted subdural electrodes after lesionectomy failed to control seizures and prior to a second operation (temporal lobectomy).

Neuropsychological Testing. Neuropsychological evaluations were conducted in 18 patients. Our standard protocol consisted of tests of global function, verbal and nonverbal abilities, and frontal lobe function with concentration on memory function. Memory assessment included evaluation of verbal recall by the Denman Neuro-psychology Memory Scale, \(^\text{19}\) nonverbal recall by the Rey–Osterrieth Complex Figure, \(^\text{20}\) and both verbal and nonverbal recognition by the Warrington Recognition Memory Test. \(^\text{21}\)

Intracarotid Amobarbital Procedure. An IAP with injection of both hemispheres at the same session was obtained in 14 patients to lateralize language. Memory function of each hemisphere was also assessed in nine patients by presenting verbal and figural material while the other hemisphere was anesthetized by the amobarbital; item recognition was tested 10 minutes after the amobarbital-induced EEG slowing had returned to baseline.

Electrocorticographic Recording. Six Group A patients had additional EEG recordings taken at a second operation when the initial lesionectomy failed to control seizures; four patients had intraoperative ECoG monitoring and two others had chronically implanted subdural electrodes. All Group B patients underwent ECoG study prior to, and on completion of, the resection, which was guided by the activity recorded. An array of 16 carbon-ball electrodes were recorded from the cortical surface while two multicontact depth electrodes were inserted freehand through the middle temporal gyrus into the region of the amygdala and the hippocampus. \(^\text{24}\) The standard trajectory of the depth electrodes was modified if tumors lay in the path. Volatile anesthetic agents were discontinued, if in use, 15 minutes before recording and methohexitol (40 mg) was administered intravenously to accentuate epileptiform activity if required. Two of the language-dominant temporal lobectomies were conducted under local anesthesia with language area mapping.

Postoperative Evaluation
During the course of regular follow-up visits, seizure histories were documented. For the purpose of this study, each patient’s present seizure status and details about anticonvulsant medication were established by chart review or telephone interviews. One of us (M.G.) collected this information without knowledge of the type of surgery the patient had undergone. At least one CT scan or, more commonly, MR image was obtained in all 30 patients in the series during their postoperative evaluation to check for recurrence.

Statistical Methods
Seizure-free outcomes of the two groups were compared by the Chi-square test. Further analysis of the outcome graded by Engel’s Class I to IV \(^\text{11}\) was performed by the Student t-test. In addition, a covariance analysis and a logistic regression analysis were conducted to detect the influence of other variables besides surgical strategy on seizure outcome. A p value of less than 0.05 was regarded as statistically significant.

Results
Patient Ages and Duration and Type of Seizures
Although the mean ages of patients in the two groups were similar at the time of surgery, the age at onset of the seizure disorder was younger among patients in Group B (mean 14 years) than among those in Group A (mean 24
Resection of temporal lobe tumors with epilepsy

years). The mean seizure duration was 3.5 years for Group A and 18 years for Group B.

Among all 30 patients who suffered complex partial seizures, half also had rare-to-frequent secondarily generalized tonic–clonic seizures. Simple partial seizures were reported by 12 patients.

Radiological Findings

Magnetic resonance images and CT scans were reviewed and analyzed for tumor size, location of the tumor relative to the temporal horn, cortical or subcortical location, and presence or absence of calcification. In Group A, nine of 16 patients had tumors larger than 2.5 cm, whereas in Group B only three of 14 patients had tumors that large. Lesions were located in the cortical area or lateral temporal cortex—lateral to the temporal horn of the lateral ventricle—with nine cases in Group A and five in Group B, and in the subcortical area or the mesial temporal structures—mesial to the temporal horn of the lateral ventricle—with seven cases in Group A and nine in Group B. Calcification of lesions was present in three Group A and four Group B patients.

Neuropsychological Evaluation

Eighteen patients had evaluation by the clinical neuropsychologist to relate material-specific memory dysfunction with laterality of the tumor in the temporal lobe. Five patients had no clear pattern of memory dysfunction, whereas one had a memory deficit contralateral to the tumor location. In 12 cases there was a material-specific memory dysfunction consistent with the laterality of the tumor. Patients with tumors of the nondominant temporal lobe exhibited poorer performances on recall of nonverbal material and those with dominant temporal lesions were associated with impaired recall of verbal material.

Intracarotid Amobarbital Procedure

Two of the Group A and 12 of the Group B patients had an IAP to lateralize language. Two patients had right hemisphere language with a left temporal tumor. Nine patients had memory testing in each isolated temporal lobe; in eight of these, memory deficits were found ipsilateral to the tumor location.

Electroencephalographic Recording

Preoperative EEG recordings were abnormal in all Group B patients except the one with the shortest duration of seizure (3 years). The abnormalities consisted of temporal epileptiform discharges ipsilateral to the lesion in 12 patients and focal slowing in six. For seven Group A patients who had EEG recordings prior to surgery, abnormalities detected by this method were usually focal slowing rather than temporal epileptiforms.

Prolonged Video–EEG Monitoring

Two of the 19 patients admitted for video–EEG monitoring did not have any seizures during this period. In the remaining patients, ictal behavioral and EEG data confirmed complex partial seizures with ictal EEG discharges at the sphenoidal electrodes in 12 patients, the anterior and midtemporal surface electrodes in three, and the subtemporal contacts of the subdural electrodes implanted in two patients.

Electrocorticographic Recording

When intraoperative ECoG was recorded in one of two Group A patients, no epileptiform discharges were recorded and only the lesion was excised. In the second patient, although spiking by depth electrode was detected in an area anterior to the tumor and in the hippocampus, the resection was not extended due to technical difficulties; this patient had a poor outcome.

The ECoG reports were reviewed for the four Group A patients at the time of the second-stage lobectomy and for all Group B patients to determine the relative location of the spiking (lateral temporal surface or amygdalohippocampal region). The spike focus was predominantly in the mesiobasal temporal region in 10 cases; tumors were located mesial to the temporal horn in four cases and lateral in six. Of the four patients with predominantly lateral temporal spiking, two had mesial tumors and two had lateral tumors. Thus, the location of the tumor relative to the temporal horn did not influence the topography of the epileptiform activity recorded at surgery.

Surgical Procedures

Two of the lesionectomies were performed using a stereotactic technique and the rest by temporal craniotomy. Temporal lobe resections were guided by ECoG monitoring and an attempt was made to resect the lesion and foci of active spiking within the limits of the noneloquent cortex and amygdalohippocampal resection. However, in two Group B cases the hippocampus was spared because of the absence of spike activity and tumor involvement.

Surgical Complications

Two Group A patients had permanent surgical morbidity; both complications were hemiparesis following lesionectomy. Occlusion of the anterior choroidal artery branch appeared to be responsible for the deficit in both. No surgical complication occurred in Group B patients.

Pathological Findings

A common histological type in this series was low-grade astrocytoma, most of which occurred in Group A (Table 1). The three glial hamartomas and three cavernous angiomas were all found in Group B. Gangliogliomas and the oligodendrogliomas occurred evenly in both Groups A and B. Thus, the two groups were not entirely homogeneous on histological criteria. Seizure outcome, however, could not be consistently correlated with pathology of the lesion.

Seizure Outcome

Follow-up periods ranged from 1 to 7 years (mean 33 months in Group A and 52 months in Group B). Seizure control was best achieved in Group B patients after an electrophysiologically guided resection (92.8% seizure free); the single exception, a patient who had a cavernous angioma resected 4 years ago, now has rare nocturnal seizures. Two patients in this group no longer take med-

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ication. By contrast, only 18.8% of the Group A patients became seizure free after lesionectomy, a statistically significant difference by Chi-square test (corrected for continuity; \( p = 0.0001 \)). Similarly, if the Engel Outcome Classes I to IV were taken to be ordinal values, the differences between the groups were significant (\( p = 0.0001 \)) as determined by either the Student t test or the Wilcoxon rank-sum test (Table 2). When lesionectomy failed to control seizures, five of eight Group A patients who underwent a temporal lobectomy as a second procedure achieved a secondary seizure-free outcome (Table 1); two no longer take anticonvulsant medication.

A covariance analysis was performed to explore whether factors other than surgery type could have influenced outcome. The difference in seizure outcomes of the two groups remained statistically significant when adjusted for the correlation with the covariates duration of seizures (\( p = 0.0006 \)) and tumor size (\( p = 0.0001 \)). A logistic regression analysis modeled with type of surgical therapy and outcome demonstrated that the addition of either of the covariates failed to improve the predicted outcomes.

### Table 1

Pathological diagnosis, outcome, and length of follow up in 30 patients with complex partial seizures and temporal lobe tumors treated surgically

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs)</th>
<th>Seizures Duration (yrs)</th>
<th>Histology</th>
<th>Tumor Size (cm)</th>
<th>Seizure Outcome Class*</th>
<th>Length of Follow Up (yrs)</th>
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* Outcome graded by Engel’s scale: I = seizure-free, auras only; II = rare or nocturnal seizures; III = worthwhile improvement, >50% reduction in frequency; IV = no worthwhile improvement. Roman numerals placed before and after arrows indicate class number after first and second procedure, respectively.

**Discussion**

In our series of patients with complex partial seizures due to temporal mass lesions, 19% of those treated by lesionectomy alone (Group A) were seizure free compared to 93% of those undergoing an electrophysiologically guided resection of the lesion and the epileptogenic zone (Group B). A limitation of our study is that patients were not randomized to receive lesionectomy or seizure surgery. Clearly, patients with a chronic seizure disorder and small, deep-seated lesions are more likely to be referred to an epilepsy service; this is reflected in the lower mean age at onset and longer seizure duration in Group B patients. However, an analysis of covariance showed that the difference in seizure outcome between the two groups remained significant even when adjusted for seizure duration and tumor location and size. Patients in Group A who underwent a second procedure for intractable epilepsy without tumor recurrence after lesionectomy would appear to be compelling evidence for the limitations of lesionectomy in terms of seizure control when the lesion is in the temporal lobe. In these cases,
completion of the temporal lobectomy achieved complete seizure control in 62.5%.

Cascino and colleagues published the long-term results of stereotactic lesionectomy: nine of 14 patients with extratemporal lesions became seizure free, whereas only two of nine patients with temporal lesions achieved this outcome. These authors also recently presented a comparative study of anterior temporal lobectomy, incorporating the lesion, and stereotactic lesionectomy, and found that 50% of lesionectomy patients and 90% of lobectomy patients were seizure free at follow-up evaluation (mean 39 months).

It is unclear why lesionectomy fails to control seizures engendered by temporal lobe tumors but increasing evidence points to hippocampal neuronal loss associated with an epileptogenic lesion in its proximity. Whether neuronal depletion is responsible for, or the result of, the seizures is moot; the disordered hippocampus can be a focus of... of... of the lesion. Conversely, there is clinical evidence that ablating the hippocampus in an anterior temporal lobectomy can be efficacious in controlling complex partial seizures that originate from an unresectable posterior temporal tumor.

Compared with autopsy controls, neuronal density is lower in the hippocampi of patients with complex partial seizures due to temporal lobe masses. This reduction was more obvious in young patients or in cases of seizures with long duration and for tumors located mesial in the temporal lobe. However, the degree of cell loss in these cases of “dual pathology” is significantly less than in mesial temporal sclerosis alone. More severe hippocampal cell loss may be associated with worse outcomes after lobectomy in patients with temporal lesions; 53% of patients with dual temporal pathology and severe hippocampal cell loss had residual seizures compared with 11% in the mild cell-loss group. Long-standing lesions, such as hamartomas and heterotopias, are more likely to be associated with severe cell loss as compared with gliomas.

Hippocampal Functional Deficits With Temporal Tumors

We attempted to explore the coexistence of hippocampal pathophysiology with the tumors of the temporal lobe. None of our operative specimens were subject to hippocampal cell quantification and in only two cases was hippocampal sclerosis reported by the neuropathologist. Similarly, hippocampal volume-loss estimation on MR imaging, which has been shown to reliably reflect cell loss, was confounded by the varying quality of the older scans, incomplete sequences, and anatomical distortions produced by some of the masses.

Memory deficits, as evaluated by neuropsychological testing and IAP, correlate with hippocampal cell loss in temporal lobe epilepsy. Of the 18 neuropsychological tests available in this study, 12 patients had memory dysfunctions consistent with laterality of the tumor-bearing temporal lobe. Similarly, in the nine IAPs in which memory function was tested, eight patients revealed memory deficits ipsilateral to the tumor location. Thus, neuropsychological criteria would support hippocampal dysfunction in the patients tested.

Another functional aspect of hippocampal sclerosis is the epileptiform potentials recorded by ECoG in affected patients. In 11 of the 24 patients who underwent ECoG recording, spiking was most obvious from the mesial contacts of the depth electrodes. However, we were not able to relate the precise location of the mass in the temporal lobe to predominantly mesial or lateral surface spike activity.

Surgical Strategies for Temporal Lesion Resection

Falconer developed and standardized the en bloc resection for temporal lobe epilepsy, and his successor who continues this technique recently reported results for 31 temporal lobe tumors with chronic complex partial seizure. Although there was histological evidence of an incomplete removal in 71% of cases, the seizure-free rate was 81% at mean follow-up interval (5.8 years). The frequency of mesial temporal sclerosis was not noted.

Hippocampal resection has been shown to cause material-specific memory impairment with declines in verbal and figural memory after dominant and nondominant temporal lobectomies, respectively. These deficits are most obvious when the hippocampus is functional as evidenced by the absence of hippocampal sclerosis on pathological examination. Preservation of the hippocampus in a temporal resection may spare the patient such deficits. Presently there is no reliable method to predict consistently the presence and degree of hippocampal cell loss in patients with seizures and a temporal lobe mass. In addition, we found tumor location to be an unreliable indicator of hippocampal epileptogenicity and were not able to relate mesial or lateral location of the tumor to hippocampal epileptogenicity as reflected by spike–wave discharges on ECoG recording.

We mainly have used intraoperative ECoG recording and occasionally implanted subdural electrodes to evaluate epileptogenicity of the hippocampus and other areas of the temporal cortex in relation to the tumor prior to resection. In two patients in our series, this allowed the temporal resection to spare the hippocampus but allow complete resection of the amygdala without compromising seizure outcome.

### Table 2

| Seizure outcome and length of follow up in 30 patients with complex partial seizures and temporal lobe tumors treated surgically |
|---|---|---|---|
| Criteria | Description | Group A No. (%) | Group B No. (%) |
| outcome* | seizure-free, auras only | 8 (50) | 13 (92.8) |
| Class I | rare seizures, nocturnal seizures | 2 (12.5) | 1 (7.2) |
| Class II | worthwhile improvement, >50% reduction in frequency | 4 (25) | 0 (0) |
| Class IV | no worthwhile improvement | 2 (12.5) | 0 (0) |
| length of follow up | mean range | 33 mos to 6–84 mos | 52 mos to 6–84 mos |

* Outcome graded by Engel’s scale Classes I through IV.
Conclusions

An analysis of 30 patients with localization-related epilepsy and temporal lobe mass lesions suggests that seizure relief is greater if the region of epileptogenicity (usually the amygdalohippocampal complex) is resected along with the tumor in a temporal lobectomy. In our patients, evidence of functional deficits and epileptogenicity of the hippocampus were often found by neuropsychological testing and IAP and by intraoperative ECoG monitoring. However, we could not relate these findings to the mesial or lateral location of the tumor in the temporal lobe, making tumor location an unreliable predictor of hippocampal involvement. Presurgical video–EEG evaluation and intraoperative mapping of interictal spike activity with ECoG monitoring at surgery may be an efficient method of delineating the epileptogenic zone related to the lesion and thus can guide a rational resection.

Acknowledgments

The authors acknowledge the assistance of Scott Michaels, Ph.D., in statistical analysis, Mary Kemper for editorial review, and Alexis Rostoker for manuscript preparation.

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Manuscript received September 27, 1993. Accepted in final form October 26, 1994.
Address reprint requests to: Hwa-shun Yeh, M.D., Department of Neurosurgery, University of Cincinnati College of Medicine, 231 Bethesda Avenue, P.O. Box 670515, Cincinnati, Ohio 45267–0515.