Electroencephalographic, Volumetric, and Neuropsychological Indicators of Seizure Focus Lateralization in Temporal Lobe Epilepsy

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Context: Anterior temporal lobectomy is an effective treatment for medically intractable temporal lobe seizures. Identification of seizure focus is essential to surgical success.

Objective: To examine the usefulness of presurgical electroencephalography (EEG), magnetic resonance imaging (MRI), and neuropsychological data in the lateralization of seizure focus.

Design: Presurgical EEG, MRI, and neuropsychological data were entered, independently and in combination, as indicators of seizure focus lateralization in discriminant function analyses, yielding correct seizure lateralization rates for each set of indicators.

Setting: Comprehensive Epilepsy Program, Shands Teaching Hospital, University of Florida, Gainesville.

Patients: Forty-four right-handed adult patients who ultimately underwent successful anterior temporal lobectomy. Left-handed patients, those with less-than-optimal surgical outcome, and any patients with a history of neurological insult unrelated to seizure disorder were excluded from this study.

Main Outcome Measures: For each patient presurgical EEG was represented as a seizure lateralization index reflecting the numbers of seizures originating in the left hemisphere, right hemisphere, and those unable to be lateralized. Magnetic resonance imaging data were represented as left-right difference in hippocampal volume. Neuropsychological data consisted of mean scores in each of 5 cognitive domains.

Results: The EEG was a better indicator of lateralization (89% correct) than MRI (86%), although not significantly. The EEG and MRI were significantly superior to neuropsychological data (66%) (P=.02 and .04, respectively). Combining EEG and MRI yielded a significantly higher lateralization rate (93%) than EEG alone (P<.01). Adding neuropsychological data improved this slightly (95%).

Conclusions: The EEG and MRI were of high lateralization value, while neuropsychological data were of limited use in this regard. Combining EEG, MRI, and neuropsychological improved focus lateralization relative to using these data independently.

Arch Neurol. 2000;57:707-712

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PATIENTS AND METHODS

PATIENTS

Forty-four patients with medically intractable unilateral temporal lobe epilepsy who underwent comprehensive presurgical epilepsy evaluations and subsequently underwent right (n=26) or left (n=18) ATL were enrolled in this study. All patients had experienced highly successful surgical outcomes and were assessed as having Engel scores29 of I at least 12 months after surgery. This allowed for the assumption that lateralization of surgical resection was the same as lateralization of the actual seizure focus. Of 61 potential patients who met all other inclusion criteria, 17 were excluded owing to having post-surgical Engel scores greater than I (Engel II, 14 patients; Engel III, 2 patients; and Engel IV, 1 patient). All patients were right-handed, at least 18 years old, and underwent presurgical neuropsychological assessment and continuous inpatient (noninvasive) video-EEG(VEEG) monitoring. Nineteen patients (12 patients who underwent right ATLs, 7 patients who underwent left ATLs) also required invasive EEG prior to surgery. All patients except for 1 in each group underwent presurgical brain MRI. Left-handed patients, those with incomplete neuropsychological data, and those with a history of neurological insult that occurred after the onset of epilepsy or that was deemed to be unrelated to their epilepsy were excluded from the study (Table 1).

MRI DATA

Presurgical imaging consisted of magnetization prepared rapid gradient echo imaging. Data were as follows: repetition time = 10 milliseconds, echo time = 4 milliseconds, volume = 160 mm, and section thickness = 1.25 to 1.40 mm, producing a gapless series of high-quality images. On the computer monitor, the hippocampus was outlined on every section that it appeared in the sagittal plane. Volumes were then calculated by measuring the hippocampal area for each section and multiplying it by the thickness of the section. The resulting volumes were summed to obtain a total volume. Each patient's right and left hippocampus was measured twice by an individual (D.J.M.) blind to patient information. The mean of these 2 values represented the total hippocampal volume. Each patient's right and left hippocampal volumes were measured twice by the International 10-20 System,20 with frequent additional use of bilateral sphenoidal electrodes. Various electrode montages and filters were used.

EEG DATA

Prior to surgery, each patient was admitted to the hospital for continuous scalp VEEG monitoring. All VEEG recordings were analyzed by the electroencephalographer (R.L.G.), who logged each seizure's clinical description, type, and, if possible, lateralization and localization of onset. Scalp electrodes were placed according to the International 10-20 System,20 with frequent additional use of bilateral sphenoidal electrodes. Various electrode montages and filters were used.

Each patient's VEEG event log was reviewed on a seizure-by-seizure basis and the electroencephalographer's interpretation of each event was entered into a database. When 2 or more seizures occurred within a 3-hour interval and were of identical lateralization and localization, they were statistically regarded as 1 event, as such circumstances make it difficult to determine whether the events are truly independent of each other. All EEG recordings significantly obscured by artifact were excluded.

The following values were obtained for each patient: total number of seizures, number of seizures lateralized to the right hemisphere, number of seizures lateralized to the left hemisphere, number of nonlateralized seizures (seizures that could not be lateralized to one hemisphere over the other). Once these data were collected, it was necessary to quantify them in a manner that would indicate difference in frequency of right and left hemispheric events, that would consider the occurrence of nonlateralized seizures, and that would place these values within the context of the total number of events recorded. Therefore, a seizure lateralization index (SLI) was calculated using the following equation:

\[
SLI = \frac{(R-L) - 0.5N}{R-L+L-N}
\]

where R indicates the number of seizures originating in the right hemisphere; L, the number of seizures originating in the left hemisphere; and N, the number of nonlateralized seizures. Nonlateralized seizures were given a weight of 0.5 which is that of a lateralized seizure, as they have a theoretically equal chance of having originated in either hemisphere.

The SLI equation yielded values ranging from 1.00 (all events lateralized to the right hemisphere) to −1.00 (all lateralized to the left hemisphere) for all patients. Values closer to 0.00 indicated varying degrees of right or left seizure frequency. The equation was designed in such a way that the occurrence of nonlateralized seizures would result in an SLI value that was less lateralizing (closer to 0.00) than it would have been had nonlateralized seizures been excluded.

NEUROPSYCHOLOGICAL DATA

Neuropsychological data were obtained from the patients' presurgical files from assessments administered 1 to 3
months before surgery. Following is a list of neuropsychological variables used in this study, and equations indicating which values were transformed into z scores to represent performance in that domain.

**Verbal Memory.** Wechsler Memory Scale-Revised¹¹: Logical Memory II (LMII), The California Verbal Learning Test¹²: Long Delay Free Recall (LDFR), Long Delay Cued Recall (LDCR), Free Recall Intrusions (FRINT), and Cued Recall Intrusions (CRINT). Using z scores, an overall verbal memory score was calculated using the following equation:

\[
(2) \text{Verbal Memory} = \frac{|(LDFR+LDCR+LMII)-(FRINT+CRINT)|}{5}
\]

**Nonverbal Memory.** Wechsler Memory Scale-Revised: Visual Reproduction II (VRII), Rey-Osterrieth Complex Figure²³: Delayed Recall (RODELAY). Using z scores, an overall nonverbal memory score was calculated using the following equation:

\[
(3) \text{Nonverbal Memory} = \frac{(RODELAY+VRII)}{2}
\]

**Language.** Wechsler Adult Intelligence Scale-Revised²⁴: Verbal IQ (VIQ), The Boston Naming Test (BNT).²⁵ Controlled Oral Word Association (COWA).²⁶ Using z scores, an overall language score was calculated using the following equation:

\[
(4) \text{Language} = \frac{(VIQ+COWA+BNT)}{3}
\]

**Visuoconstructive.** Rey-Osterrieth Complex Figure: Copy (ROCOPY), Wechsler Adult Intelligence Scale-Revised: Block Design (BD) and Object Assembly (OA) tests. Using z scores, an overall visuoconstructive score was calculated using the following equation:

\[
(5) \text{Visuoconstructive} = \frac{(ROCOPY+BD+OA)}{3}
\]

**Motor.** Finger Tapping Test (FTT)²⁷ (dominant and nondominant hands), Grooved Pegboard Test (GPT)²⁸ (dominant and nondominant hands). Using z scores, an overall motor score was calculated using the following equation:

\[
(6) \text{Motor} = \frac{(Right FTT+Right GPT)-(Left FTT+Left GPT)}{2}
\]

Distributed across 44 subjects and 748 neuropsychological data points in the study were 20 missing values. These were replaced using the following procedure: Correlations were calculated among neuropsychological variables for the entire sample. When a subject was missing a value, his or her scores on the 5 neuropsychological variables most strongly correlated with that variable were entered into a multiple regression, thereby generating an individualized, predicted score for that subject. The replacement of these 20 values altered group means only to an extremely small degree, and did not change any subject’s predicted lateralization.

**STATISTICAL ANALYSES**

Descriptive statistics were derived for demographic and illness-related variables, SLI, left and right hippocampal volumes, and the difference between them (DHF), and neuropsychological domain scores. The statistical analyses used in this study were planned and conducted in consultation with one of us (J.J.A.). Two-tailed t tests were used to compare the means of these variables for the left ATL group with the right ATL group. The SLI was then entered into a discriminant function analysis as the sole predictor of seizure focus lateralization (whether the patient subsequently underwent left or right ATL). Difference between the left and right hippocampal volumes was then entered as the sole predictor of lateralization, and then the set of 5 neuropsychological domain scores were entered together as predictors. This allowed for comparison of correct lateralization rates among EEG, MRI, and neuropsychological data when these domains were used in isolation. Subsequently, these 3 domains of data were entered as predictors of lateralization in 4 subsequent discriminant function analyses, allowing for all possible combinations of SLI, DHF, and neuropsychological data to be used as predictors.

All discriminant function analyses were conducted using the “leave-one-out” (also called “jackknife”) method. This allowed for prediction of each patient’s seizure focus lateralization to be based on coefficients calculated independently of that patient’s own data. The resulting classification rates are, therefore, cross-validated, and are not artificially inflated as sometimes occurs in traditional discriminant analysis.

Three McNemar tests for 2 x 2 tables were used to compare the correct lateralization rates derived from using SLI, DHF, and the set of 5 neuropsychological domain scores separately as predictors. The effect of using these 3 domains of data in varying combinations was investigated using Rao’s test for additional information, in which the Wilks λ value from each combination of predictors’ discriminant function analysis was obtained and converted into a Hotelling T² statistic. The 2 Hotelling T² statistics were then used to compute an F test score of whether combining the domains increased the correct lateralization rate. An α level of .05 was used for all of these tests.

In the current study, we used presurgical EEG, MRI, and neuropsychological data to lateralize seizure foci in a group of patients who underwent successful ATL. This not only allowed for direct comparison of these individual techniques within a single patient population, but also enabled us to explore the degree to which combining these domains of data would increase correct lateralization rates. We hypothesized that EEG would yield the highest correct lateralization rate, followed by MRI, and then neuropsychological data. We also predicted that combining EEG, MRI, and neuropsychological data would increase correct lateralization rates compared with using them in isolation.

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**RESULTS**

The groups who underwent right and left ATLs did not differ statistically significantly for demographic or illness-
related variables (Table 1). **Table 2** contains descriptive statistics regarding the number and lateralization of seizures experienced by all patients and the groups who had right and left ATLs during inpatient VEEG monitoring, and the resulting mean SLI values for these groups. A 2-tailed t test revealed that the group who underwent left ATL had a statistically significant lower mean SLI ($t_{51,10}=9.21, P<.001$) than did the group who underwent right ATL.

**Table 3** contains descriptive statistics regarding hippocampal volumes. Two-tailed t tests revealed that the group who underwent right ATL had a significantly smaller mean right hippocampal volume ($t_{49}=-4.65, P<.001$) and a significantly lower mean DHF ($t_{49}=-7.34, P<.001$), than did the group who underwent left ATL, and the group who underwent right ATL had a significantly smaller mean left hippocampal volume than the group who underwent right ATL ($t_{49}=3.06, P<.004$).

**Table 4** contains descriptive statistics for the 5 neuropsychological domain scores. Two-tailed t tests revealed that the group who underwent left ATL had significantly lower mean language and verbal memory domain scores ($t_{42}=2.07, P=.04; t_{42}=2.22, P=.03$, respectively) than the group who underwent right ATL, while other differences were statistically nonsignificant.

The rates at which SLI, DHF, and the 5 neuropsychological domain scores, used independently and in combination, were used to correctly predict seizure focus lateralization are given in **Table 5**. The following classification rates were compared: SLI vs DHF, SLI vs the 5 neuropsychological domain scores, DHF vs the 5 neuropsychological domain scores, SLI and DHF combined vs SLI, the 5 neuropsychological domain scores and SLI combined vs SLI, and finally, the 5 neuropsychological domain scores, SLI, and DHF combined vs SLI and DHF combined. The results of these tests are presented below.

McNemar tests for $2 \times 2$ tables were used to test the first 3 of the above comparisons (ie, SLI vs DHF, SLI vs the 5 neuropsychological domain scores, and DHF vs the 5 neuropsychological domain scores). Again, the exact statistical significance of each comparison was obtained.

**Table 1. Descriptive Statistics for Demographic and Illness-Related Variables**

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Patients (N = 44)</th>
<th>LATL† (n = 26)</th>
<th>RATL† (n = 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, y</td>
<td>34.14 (9.95)</td>
<td>33.65 (10.26)</td>
<td>34.83 (9.75)</td>
</tr>
<tr>
<td>Education, y</td>
<td>12.85 (2.35)</td>
<td>12.81 (2.19)</td>
<td>12.92 (2.64)</td>
</tr>
<tr>
<td>Age at onset of epilepsy, y</td>
<td>11.21 (10.86)</td>
<td>11.90 (11.92)</td>
<td>10.22 (0.34)</td>
</tr>
<tr>
<td>Duration of epilepsy, y</td>
<td>23.02 (10.50)</td>
<td>22.12 (10.42)</td>
<td>24.33 (10.78)</td>
</tr>
<tr>
<td>% Female</td>
<td>54.54</td>
<td>61.11</td>
<td>50.00</td>
</tr>
</tbody>
</table>

**Table 2. Descriptive Statistics for Electroencephalographic Variables**

<table>
<thead>
<tr>
<th>Seizure Variable</th>
<th>All Patients (N = 44)</th>
<th>LATL† (n = 26)</th>
<th>RATL† (n = 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total§</td>
<td>5.36 (3.10)</td>
<td>5.19 (2.68)</td>
<td>5.81 (3.68)</td>
</tr>
<tr>
<td>Hemisphere of onset, No.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Right</td>
<td>1.95 (2.27)</td>
<td>0.27 (1.04)</td>
<td>4.39 (3.85)</td>
</tr>
<tr>
<td>Left</td>
<td>2.70 (2.56)</td>
<td>4.12 (2.08)</td>
<td>0.67 (1.64)</td>
</tr>
<tr>
<td>Nonlateralized</td>
<td>0.70 (1.81)</td>
<td>0.81 (2.12)</td>
<td>0.56 (1.29)</td>
</tr>
<tr>
<td>SLI§</td>
<td>-0.23 (0.87)</td>
<td>-0.83 (0.36)</td>
<td>0.63 (0.60)</td>
</tr>
</tbody>
</table>

**Table 3. Descriptive Statistics for Volumetric Variables**

<table>
<thead>
<tr>
<th>Volumetric Variable</th>
<th>All Patients (N = 44)</th>
<th>LATL† (n = 26)</th>
<th>RATL† (n = 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hippocampal volume, cm³</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean right</td>
<td>3.13 (0.71)</td>
<td>3.47 (0.55)</td>
<td>&gt;2.63 (0.62)</td>
</tr>
<tr>
<td>Mean left</td>
<td>3.14 (0.73)</td>
<td>2.89 (0.77)</td>
<td>&lt;3.52 (0.46)</td>
</tr>
<tr>
<td>DHF†</td>
<td>-0.02 (0.97)</td>
<td>0.58 (0.62)</td>
<td>&gt;-0.90 (0.66)</td>
</tr>
<tr>
<td>%RHS§</td>
<td>30.95</td>
<td>0.00</td>
<td>76.47</td>
</tr>
<tr>
<td>%LHS§</td>
<td>30.95</td>
<td>52.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

**Table 4. Descriptive Statistics for 5 Neuropsychological Domain Scores**

<table>
<thead>
<tr>
<th>Variable</th>
<th>All Patients (N = 44)</th>
<th>LATL† (n = 26)</th>
<th>RATL† (n = 18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Language</td>
<td>-1.20 (1.19)</td>
<td>-1.50 (1.11)</td>
<td>&lt;-0.78 (1.19)</td>
</tr>
<tr>
<td>Verbal memory</td>
<td>-1.26 (1.29)</td>
<td>-1.60 (1.28)</td>
<td>&lt;-0.76 (1.19)</td>
</tr>
<tr>
<td>Nonverbal memory</td>
<td>-0.44 (1.03)</td>
<td>-0.33 (0.92)</td>
<td>-0.61 (1.18)</td>
</tr>
<tr>
<td>Visuoconstructive</td>
<td>-0.35 (0.82)</td>
<td>-0.29 (0.85)</td>
<td>-0.44 (0.79)</td>
</tr>
<tr>
<td>Motor</td>
<td>0.45 (2.36)</td>
<td>0.39 (1.94)</td>
<td>0.54 (2.92)</td>
</tr>
</tbody>
</table>

*All values are expressed as mean (SD). When compared for statistical significance, all groups were not significantly different at the $\alpha$ level of .05.
†LATL indicates patients who eventually underwent left anterior temporal lobectomy; RATL, patients who eventually underwent right anterior temporal lobectomy.
‡DHF indicates mean difference in hippocampal formation volume (right−left, in cubic centimeters).
§SLI indicates seizure lateralization index. (See equation 1 in the “EEG Data” subsection of the “Patients and Methods” section for an explanation of the calculations for each variable.) The patients in the LATL group differed significantly ($P<.001$) from the patients in the RATL group.

*All values are expressed as mean (SD). The greater than (>) or less than (<) sign indicates the directionality of the statistically significantly differences between the groups ($P<.01$).
†LATL indicates patients who eventually underwent left anterior temporal lobectomy; RATL, patients who eventually underwent right anterior temporal lobectomy.
‡DHF indicates mean difference in hippocampal formation volume (right−left, in cubic centimeters).
§%RHS indicates percentage of each group meeting criteria for significantly smaller right hippocampus (DHF < −0.45 cm³); %LHS, percentage of each group meeting criteria for significantly smaller left hippocampus (DHF > +0.55 cm³).
from the binomial distribution, and it is this value that is reported below. The classification rate for SLI (88.10% correct) and that for DHF (85.71%) were not significantly different ($P = .99, n = 42$). Classification rate for SLI (88.63%) was significantly better than that for the 5 neuropsychological domain scores (65.91%) ($P = .02, n = 44$). Classification rate for DHF (85.71%) was also significantly better than that for the 5 neuropsychological domain scores (61.90%) ($P = .04, n = 42$). On an exploratory basis, the classification rate for DHF was also examined among only those 26 patients who met criteria for significant hippocampal asymmetry (DHF $< -0.15$ cm$^3$ or DHF $> 0.55$ cm$^3$). Of these 100% were correctly lateralized using DHF.

F tests were used to test the final 3 comparisons described above (ie, SLI and DHF combined vs SLI, the 5 neuropsychological domain scores, SLI, and DHF combined vs SLI and DHF combined). Results indicated that classification rate for SLI and DHF combined (92.86% correct) was significantly better than that for SLI alone (88.10% correct), $F_{1,26} = 13.76, P = .001, n = 42$. Classification rate for the 5 neuropsychological domain scores and SLI combined (90.91%) was not significantly different from that for SLI alone (86.63%) ($n = 44$). Finally, classification rate for 5 neuropsychological domain scores, SLI, and DHF combined (95.24%) was not significantly different from that for SLI and DHF combined (92.86% correct) ($n = 42$).

Exploratory examination of the data revealed that the patient in the right ATL group who was mislateralized had an SLI value of −1.00, because all of his seizures falsely appeared to originate in the left hemisphere on ictal scalp EEG. Furthermore, although he did not have a significant degree of hippocampal asymmetry, his MRI data were also mislateralizing when used as the sole predictor. In this study, only the 5 neuropsychological domain scores were able to lateralize this patient correctly. Clinically, this patient underwent invasive EEG monitoring that revealed the right hemisphere focus. The patient in the left ALT group who was mislateralized had an SLI value of 0.29, falsely indicating a tendency toward right lateralization. In this study, this patient would have been correctly lateralized had hippocampal volumes or the 5 neuropsychological domain scores been used to predict lateralization. Clinically, invasive EEG monitoring was used to identify the left hemisphere focus.

Following is a description of each set of predictors used in these discriminant analyses, the resulting Wilks $\lambda$ values, and levels of statistical significance. Entering SLI as the sole predictor of seizure focus lateralization yielded the following results: Wilks $\lambda = 0.292 (P < .001), n = 44$. The DHF as the sole predictor: Wilks $\lambda = 0.426 (P < .001), n = 42$. The 5 neuropsychological domain scores as predictors: Wilks $\lambda = 0.766, (P > .05), n = 44$. Combined DHF and SLI as predictors: Wilks $\lambda = 0.228 (P < .001), n = 42$. Combined SLI and the 5 neuropsychological domain scores as predictors: Wilks $\lambda = 0.262 (P < .001), n = 44$. Combined DHF and the 5 neuropsychological domain scores as predictors: Wilks $\lambda = 0.384 (P < .001), n = 42$. Combined DHF, SLI, and the 5 neuropsychological domain scores as predictors: Wilks $\lambda = 0.210 (P < .001), n = 42$.

**Table 5. Correct Seizure Focus Lateralization Rates Using NP, SLI, and DHF as Indicators**

<table>
<thead>
<tr>
<th>Predictor Variables</th>
<th>LATL ($n = 26$)</th>
<th>RATL ($n = 18$)</th>
<th>All Patients ($n = 44$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>NP, DHF, and SLI</td>
<td>96.00 (25)</td>
<td>94.12 (17)</td>
<td>95.24 (42)</td>
</tr>
<tr>
<td>DHF and SLI</td>
<td>92.00 (25)</td>
<td>94.12 (17)</td>
<td>92.86 (42)</td>
</tr>
<tr>
<td>NP and SLI</td>
<td>92.31 (26)</td>
<td>88.89 (18)</td>
<td>90.91 (44)</td>
</tr>
<tr>
<td>SLI</td>
<td>92.31 (26)</td>
<td>83.33 (18)</td>
<td>88.63 (44)</td>
</tr>
<tr>
<td>DHF</td>
<td>88.00 (25)</td>
<td>82.35 (17)</td>
<td>85.71 (42)</td>
</tr>
<tr>
<td>NP and DHF</td>
<td>84.00 (25)</td>
<td>76.47 (17)</td>
<td>80.95 (42)</td>
</tr>
<tr>
<td>NP</td>
<td>69.23 (26)</td>
<td>61.11 (18)</td>
<td>65.91 (44)</td>
</tr>
</tbody>
</table>

*All values are expressed as percentage correct, ie, percentage of each group for which lateralization of seizure focus was correctly predicted by entering various combinations of predictor variables into discriminant analyses (size of subsample). NP indicates all 5 neuropsychological domain z scores; SLI, seizure lateralization index (see equation 1 in the “EEG Data” subsection of the “Patients and Methods” section); DHF, difference in hippocampal formation volume (right − left, in cubic centimeters); LATL, patients who eventually underwent left anterior temporal lobectomy; and RATL, patients who eventually underwent right anterior temporal lobectomy.

Our data support our hypotheses and are consistent with the existing literature. Ictal scalp EEG indicated seizure focus lateralization at a higher rate than MRI-based hippocampal volume differences, but this was not a statistically significant difference. Both EEG and MRI were significantly superior to the 5 neuropsychological domain scores. Combining EEG and MRI data yielded a significantly higher correct lateralization rate than using EEG alone. Despite its statistical significance, this improvement in lateralization was minor and of questionable clinical importance. Combining all 3 domains of data yielded the highest correct lateralization rate, but this was not a statistically significant improvement over using combined EEG and MRI data.

The fact that ictal scalp EEG data indicated lateralization at a rate approaching 90% is not surprising. This is consistent with existing studies and with the fact that this group of patients had discrete unilateral seizure foci. The inclusion of interictal and invasive EEG data would likely have yielded an even higher lateralization rate.

Magnetic resonance imaging–based hippocampal volume differences also indicated lateralization with a high degree of accuracy, despite the fact that only 62% of our patients met criteria for significant hippocampal asymmetry. Therefore, these volumes lateralized foci quite accurately, despite the fact that these data were statistically forced to indicate lateralization in many cases in which most clinicians would have interpreted the MRI as nonlateralizing. Among those meeting criteria for significant hippocampal asymmetry ($n = 26$), the correct lateralization rate was 100%. This is consistent with very high MRI-based lateralization rates reported in the literature, involving patients with postoperatively confirmed mesial temporal sclerosis.

Consistent with past studies,14–18 neuropsychological data correctly lateralized seizure foci in only 63% of
cases. Despite this, both patients who were mislateralized when EEG, MRI, and neuropsychological data were combined, were correctly lateralized based on neuropsychological domain scores alone. Clinically, both required invasive EEG monitoring prior to surgery, as did 43% of all patients in the study.

It is surmised that neuropsychological performance is sensitive to factors such as education, affective issues, medication, seizure frequency, age of epilepsy onset, and duration of illness—factors that may not similarly reduce the usefulness of MRI or EEG. Despite these limitations, presurgical neuropsychological data remain valuable in the prediction of postsurgical functioning, and neuropsychological tasks are a critical component of the intracarotid amobarbitol procedure. Other neuropsychological services of significant benefit to patients and their families include cognitive rehabilitation and presurgical and postsurgical counseling.

That the combination of EEG, MRI, and neuropsychological data correctly lateralized temporal lobe seizure focus at a rate exceeding 95% in our study is certainly encouraging. However, it must be reiterated that this patient population had discreet seizure foci and, therefore, represent the cases most able to be lateralized.

Additional studies are needed to investigate and improve lateralization and localization strategies in seizure disorders with more complex presentations.

Accepted for publication October 27, 1999.

This study was supported in part by a research award grant from the Society for a Science of Clinical Psychology, Division 12, Section III, American Psychology Association, Washington, DC (Dr Moser).

We gratefully acknowledge the assistance of Christiana Leonard, MD, and Timothy Lucas, MD, who were generous with their time and resources and provided valuable neuroimaging consultations.

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