Ictal localization of temporal lobe seizures with scalp/sphenoidal recordings

M.W. Risinger, MD; J. Engel, Jr., MD, PhD; P.C. Van Ness, MD; T.R. Henry, MD; and P.H. Crandall, MD

Article abstract—We assessed the reliability and accuracy of scalp/sphenoidal recordings for ictal localization by retrospectively analyzing 706 noninvasive ictal recordings from 110 patients who subsequently underwent stereoencephalographic evaluation. Strictly defined unilateral temporal/sphenoidal ictal patterns correctly predicted findings of depth electrode examination in 82 to 94% of cases. These strictly defined predictive patterns could be detected with excellent interrater reliability. The patterns are misleading in only a minority of cases, but cannot be used in isolation for definite ictal localization.

Some patients with medically refractory complex partial seizures are candidates for neurosurgical intervention. The pre-surgical evaluation process usually includes a period of noninvasive neurophysiologic monitoring during which the patient's spontaneous seizures are recorded using scalp or scalp and sphenoidal electrodes. This recording period allows for a preliminary assessment of the unifocal or multifocal nature of the refractory seizures and the region or regions of the brain from which the typical seizures are likely to originate. Surface EEG recordings obtained during complex partial seizures sometimes contain easily recognized rhythmic patterns. These rhythmic patterns provide evidence for a localized onset of the seizure when they appear as an initial feature over a single temporal region prior to the occurrence of alteration of consciousness (as documented by simultaneous video monitoring of ictal behavior). However, the localizing value of such patterns is controversial; the accuracy and reliability of noninvasive recordings for ictal localization have been questioned.

During 11 years of prospective clinical experience, we have recognized that a large number of noninvasive recordings of complex partial seizures of presumed temporal lobe origin contain prominent localized or lateralized electrographic features. Such findings may be misleading, however, in identifying a temporal ictal focus. We have also noted the frequent occurrence of a typical electrographic pattern that contains a clearly discernible rhythmic discharge of theta or faster frequencies that localize to 1 temporal or sphenoidal location. Since the localizing accuracy of this particular electrographic pattern has not been adequately assessed, we retrospectively reanalyzed the scalp/sphenoidal ictal recordings from 110 patients with medically refractory complex partial seizures in whom a temporal lobe ictal onset was suspected and who subsequently had stereotactic implantation of bitemporal or bitemporal and bifrontal depth electrodes for definite ictal localization. We devised a system of classification for noninvasive recordings that relies upon the recognition of prominent focal sphenoidal or temporal ictal patterns and requires little subjective judgment on the part of the electroencephalographer. We then retrospectively examined the reliability and predictive accuracy of these so-classified focal ictal patterns by comparing assessments of qualified examiners, and by comparing predicted localizations with findings from depth electrode recordings.

We hypothesized that, within a population of patients undergoing a presurgical evaluation of medically refractory complex partial seizures, strictly defined focal temporal ictal patterns seen in noninvasive recordings reliably and accurately predict ipsilateral temporal localization obtained by depth electrode studies.

Methods. Inclusion criteria. The ictal recordings to be analyzed were taken from the series of patients with medically refractory complex partial seizures who have participated in the Clinical Neurophysiology Program at UCLA since 1977. One hundred thirty patients had an initial period of noninvasive ictal monitoring, which was then followed (with variable latency) by a period of invasive ictal monitoring with stereotactically placed temporal or temporal and frontal depth electrodes. Twenty of the 130 patients with both noninvasive ictal recordings and depth electrode implantation were excluded from the current analysis. Three patients were ex-
Figure 1. This surface recording is an example of an initial focal ictal pattern. In this case, the focal pattern erroneously suggested a right temporal origin for the patient's seizures. A left temporal origin was subsequently demonstrated. The arrow indicates the point at which the characteristic rhythmic activity appears.

Figure 2. This surface recording also contains an initial focal pattern. The initial localizing discharge (indicated by the 1st arrow) is slower than 5 Hz, but a 5-Hz pattern is seen in the same distribution several seconds later. The 2nd arrow indicates the point at which clinical ictal behavior was noted.

cluded because no seizures were recorded after depth electrode implantation. Nine patients were excluded because full hard-copy records of all ictal events could not be retrieved. One patient was excluded because the noninvasive recordings were technically inadequate, preventing adequate analysis. Seven patients who had both noninvasive and invasive monitoring periods were excluded from this analysis because the results of the preliminary evaluation strongly indicated an extratemporal location (which was subsequently confirmed). One hundred patients were, therefore, included in this study.

All patients described in the retrospective analysis had invasive depth electrode implantation after initial noninvasive monitoring because available evidence was considered insufficient for definite localization of ictal origin. All patients were fully counseled as to the risks and benefits of depth recording procedures and all signed informed consents. These examinations have been approved by the Human Subject Protection Committee of the UCLA Center for the Health Sciences.

Technique of recording. All noninvasive ictal recordings were obtained using a full complement of scalp electrodes placed according to the International 10-20 system, except that ear electrodes were not employed. Depth electrodes were stereotactically placed using the technique described by Engel et al. All patients had bilateral sphenoidal wire electrodes placed. The technique of EEG/video telemetry recording...
and rationale for montage selection have been previously described.  

**Classification.** The 1st author (M.W.R.) devised a classification paradigm that required a set of simple determinations for each ictal recording. The 1st decision required determination of the presence or absence of a unilateral temporal/sphenoidal rhythmic discharge of 5 Hz or faster within the first 30 seconds of the ictal recording. The 2nd decision required a determination of whether the identified discharge was the 1st electrographic feature other than a diffuse suppression of background activity, or whether the rhythmic discharge appeared only after some other type of lateralized or diffuse electrographic change. Recordings with a focal pattern of 5 Hz or faster as the 1st ictal electrographic change (other than diffuse suppression of background activity) were designated as initial focal recordings. A focal temporal/sphenoidal discharge slower than 5 Hz or an isolated focal temporal/sphenoidal transient was also designated as initial focal pattern if it was followed, within 30 seconds, by a 5-Hz rhythm in the same distribution. Recordings in which a temporal rhythmic pattern of 5 Hz or faster was noted after the appearance of some other type of diffuse or lateralized electrographic change were designated as delayed focal recordings. Recordings that lacked a clearly defined temporal rhythm of 5 Hz or faster were designated as nonlocalizing even if some other type of lateralized or focal electrographic change seemed apparent (see figures 1, 2, and 3 for examples).

We analyzed 706 ictal recordings, using the criteria outlined above. Behavioral analysis was specifically excluded from the classification process. A hard copy of each ictal recording was used for analysis. The 1st analysis was performed by 1 author (M.W.R.) and confirmed by a 2nd (J.E.). Neither examiner was blinded to patient identity. If more than one electrographic pattern was encountered in a single patient, the classification implying the most secure localization was arbitrarily chosen for that patient’s set of recordings. Thus, if both focal and nonfocal patterns were noted in a single patient with a consistent clinical seizure type, the patient was classified as having a focal pattern. If both initial and delayed focal patterns over 1 temporal area were noted in a single patient, the patient was classified as showing an initial focal pattern, presuming that an earlier focal pattern provided a more secure assessment of localization.

For the purposes of testing our hypothesis, an initial or delayed focal ictal rhythm maximal at one sphenoidal or temporal location was used to “predict” an ipsilateral temporal onset on depth examination.

Depth recordings for each of the patients had been previously analyzed in detail for clinical purposes. For purposes of comparison with the noninvasive ictal recordings, we obtained only a global assessment that indicated whether depth electrode studies localized ictal onset to one or the other temporal regions, localized onset to other brain regions, or were nonlocalizing.

**Interrater reliability.** Reliability of the classification scheme was assessed as follows: 20 representative ictal recordings were selected by the 1st author as teaching examples for 2 additional qualified electroencephalographers (T.R.H. and P.V.N.). Following classification of these and subsequent discussion and resolution of any disagreements, an additional 40 representative ictal recordings were then selected by the 1st author (M.W.R.) to be analyzed in blinded fashion by the 2 additional EEGers. A major disagreement between a pair of examiners was recorded if 1 examiner rated a given ictal recording as localizing and the 2nd did not, or if there was disagreement between 2 examiners as to the localization of a focal discharge. A minor disagreement was recorded if the 2 examiners agreed on the presence of a focal 5-Hz or faster pattern and agreed on its lateralization, but differed in whether the pattern in question was an initial or delayed focal pattern. Interrater agreement for each pair of examiners (including the nonblinded 1st author) was then calculated and expressed as the kappa value (the percentage overall agreement adjusted for chance). Kappa is determined by the formula po - pc/1 - pc, where po is percentage overall agreement and pc is percentage overall agreement attributable to chance. The kappa value itself can be tested for statistical significance. Standard error of kappa was calculated in each instance.
Results. Accuracy (table 1). The 706 ictal recordings from 110 patients were reviewed, with consensus by the 2 unblinded examiners. Fifty-seven patients had ictal recordings with focal rhythmic activity (initial or delayed) over 1 sphenoidal/temporal region. Fifty-three patients had nonfocal ictal recordings.

Twenty-nine patients had 1 or more ictal recordings that contained an initial focal pattern. In 25 of these 29 patients, the presence of an initial focal discharge correctly predicted an ipsilateral temporal ictal onset, as demonstrated by subsequent depth electrode studies (p = 0.0001, binomial test for large samples). In 4 patients this prediction was incorrect. In 1 case, the initial focal pattern appeared contralateral to the depth-recorded onset of the patient's typical seizures. In the other misleading cases, depth electrode studies were nonlocalizing.

Twenty-eight patients had 1 or more noninvasive ictal recordings with a delayed focal rhythmic pattern. In 22 of the 28 cases, the presence of a delayed rhythmic pattern correctly predicted an ipsilateral temporal onset as confirmed by subsequent depth electrode studies (p = 0.002, binomial test for large samples). In 6 cases this prediction was incorrect. In one patient the delayed focal pattern was falsely lateralizing (ie, a focal origin was documented, with depth electrodes, in the contralateral temporal lobe). In the remaining 5 cases with ictal recordings demonstrating a delayed focal pattern, depth electrode recordings did not demonstrate a unifocal temporal ictal onset. The predictive accuracy of the initial focal pattern compared with the delayed focal pattern was not statistically significant (p = 0.20, Fisher's exact test).

Twenty-four of the 57 patients with focal recordings showed variability in their ictal electrographic patterns, with some recordings being classified as nonlocalizing (ie, lacking the critical 5-Hz pattern). Three of 4 of the initial focal misleading cases had some seizures with nonlocalizing electrographic features. Five of 6 of the delayed focal misleading cases had some seizures with nonlocalizing electrographic features. In the remaining 16 cases of patients having both focal and nonlocalizing recordings during their telemetry period, the focal recordings were correctly predictive. Patients with a mixture of focal recordings and nonlocalizing recordings during their telemetry period were statistically more likely to have misleading recordings when compared with patients with uniformly focal recordings during their telemetry period (p = 0.009, Fisher's exact test). No patient in this series had a noninvasive classification that predicted independent focal seizures from each hemisphere.

Of the 53 patients in this series who had noninvasive ictal recordings that were classified as consistently nonlocalizing using the criteria described above, 34 patients had subsequent depth recordings that localized their typical seizures to one or the other temporal lobe. Twenty-seven of the 53 patients had ictal recordings that showed some degree or type of lateralizing or localizing ictal electrographic discharge but lacked a 5-Hz or faster temporal rhythm. The predictive accuracy of this less specific type of electrographic change was poor. In 14 of 27 patients, the presence of a less specific lateralized or focal change was misleading, either falsely lateralizing a temporal onset or predicting a temporal onset when none was subsequently demonstrated with invasive monitoring techniques (table 1). The predictive accuracy of this less rigidly defined type of lateralized electrographic change was not statistically different from that provided by sets of recordings having a mixture of focal and nonfocal designations (p > 0.05, chi-square test).

Reliability (table 2). Major disagreements between pairs of examiners were recorded in 5 to 10% of the 40 selected ictal recordings. Minor disagreements were recorded in 17 to 27% of cases, where there were no major disagreements. All major disagreements were concerned with the presence or absence of a significant localizing pattern. If the 2 examiners in an individual instance agreed that a focal pattern was present, there was never a disagreement about the lateralization of the focal pattern in question. Kappa value was calculated for each examiner pair for localization versus nonlocalization, and for initial versus delayed pattern when localization was agreed upon. The values for each examiner pair are listed in table 2. All kappa values for localization versus nonlocalization were greater than
In 18% of all cases (and in 33% of cases with a mixture of focal and nonfocal ictal recordings), the presence of a well-defined rhythmic temporal or sphenoidal ictal discharge was misleading in that the prediction of an ipsilateral temporal depth onset was not confirmed at the time of invasive monitoring.

Previous reports have described the entity of "false lateralization" of surface ictal discharges in patients with complex partial seizures of temporal origin. An earlier systematic study with limited surface sampling found no evidence for this potential problem. Two additional patients in this series with more consistently defined criteria are now included in this category. The most common predictive error in this series of ictal recordings was not a false lateralization of a temporal ictal discharge, but rather the false prediction of a focal temporal discharge when none was subsequently documented from either temporal lobe. One implication of this finding is that false localization within a hemisphere may be a more frequently encountered problem with surface ictal recordings than false lateralization of a temporal ictal discharge, and that complex partial seizures of extratemporal origin sometimes produce surface ictal electrographic patterns that are similar to those seen with seizures of mesial temporal origin.

This retrospective study has limitations. The patient population is highly selective and includes only those patients with medically refractory complex partial seizures who were judged on clinical grounds as likely to have a temporal focus for their seizures. Our conclusions would apply only to a similar group and cannot be directly extrapolated to populations with a wider clinical spectrum of seizure types. This study examines the usefulness of noninvasive recordings for prediction of findings with a specific invasive study technique; the usefulness for prediction of surgical outcome is not directly addressed.

We specifically excluded an analysis of ictal behavior. Prevailing opinion suggests that localized surface ictal patterns that appear after the onset of grossly observable ictal behavioral change may be inaccurate for localization, and that patterns appearing before consciousness is impaired are valid. We can neither confirm nor deny such claims, but are impressed with the difficulty encountered when attempting to make a second-by-second analysis of behavior to determine the precise time after which consciousness is impaired. This problem has been addressed in detail by others. From a practical standpoint, clear rhythmic ictal patterns are rarely encountered in surface recordings prior to some type of clinical behavioral change. The 1 patient in our series with an initial focal pattern that was falsely lateralizing (as proved by subsequent depth electrode studies and successful temporal lobectomy with 3 years' follow-up), displayed this falsely lateralizing pattern at a time when he showed no impairment of perception, memory, or consciousness (figure 1). We believe that an analysis of clinical ictal behavior is a critical component in the diagnostic evaluation, but that valuable information contained in the ictal electrographic pattern should not be discounted merely because it occurs after ictal behavior becomes clinically apparent. Conversely, the localizing validity of a focal temporal ictal pattern pre-
ceding alteration of consciousness cannot be assumed.

Spencer et al\textsuperscript{7} have reported their experience with the reliability and accuracy of localization by scalp ictal EEG in 54 patients. That study suggested that scalp recordings were unreliable and inaccurate for ictal localization, but also suggested that noninvasive localization of temporal lobe seizures might be possible if a consistent and reproducible set of evaluation criteria were developed. We have developed such criteria. Our better ability to reliably and accurately localize temporal ictal foci is likely due to 2 factors: (1) our montage construction, with sphenoidal electrodes in the middle of a continuous chain across both temporal regions, allows for an efficient and consistent recognition of the critical ictal pattern component, and (2) our scheme of analysis was based on a prescribed, consistent, and limited set of possible interpretation criteria designed to be sensitive to temporal localization and allowing for little subjective judgment on the part of the examiner. We have devised a formal set of criteria which, while not perfect, has enabled us to tentatively localize a larger percentage of our patients with medically refractory seizures by noninvasive study. Our results also confirm, however, that scalp/sphenoidal recordings are subject to error even in the best of circumstances, and should never be used in isolation for presurgical localization.

References