Published in final edited form as:

J Clin Neurophysiol. 2013 February ; 30(1): 45–50. doi:10.1097/WNP.0b013e31827edca4.

Noninvasive Predictors of Subdural Grid Seizure Localization in Children With Nonlesional Focal Epilepsy

Giridhar P. Kalamangalam^{*}, Elia M. Pestana Knight[†], Shyam Visweswaran[‡], Ajay Gupta[†]

^{*}Department of Neurology, University of Texas Health Science Center, Houston, Texas, U.S.A.

[†]Section of Pediatric Epilepsy, Epilepsy Center, Neurological Institute, Cleveland Clinic, Cleveland, Ohio, U.S.A.

[‡]Department of Biomedical Informatics, University of Pittsburgh, Pittsburgh, Pennsylvania, U.S.A.

Abstract

Purpose: Subdural grid evaluation (SDE) in refractory focal epilepsy aims to precisely define the ictal onset zone and map eloquent cortex. In a small but significant proportion of children, SDE shows multifocal or diffuse, rather than focal, seizure onset. Resective epilepsy surgery is denied, or is unsuccessful, in the majority of such patients. The authors investigated whether the non-invasive data could be abstracted to predict subsequent SDE electrographic outcome (focal vs. multifocal/diffuse ictal onset).

Methods: The authors retrospectively reviewed charts of 66 children with refractory focal epilepsy undergoing SDE at Cleveland Clinic over a 7-year period, studied previously by Pestana Knight et al. A semiquantitative “score” summarizing the localizing value and concordance between selected noninvasive investigations (interictal and ictal EEG; positron emission tomography [PET], and/or single-photon emission computed tomography [SPECT]), as well as Bayesian predictors of individual investigations and their combinations, were adapted from the study of Kalamangalam et al to the subset of patients with nonlesional cranial MRI.

Results: Forty (60.6%) patients had a single MRI brain lesion, 7 (10.6%) had bilateral or diffuse MRI changes, and 19 (28.8%) were nonlesional. Subdural grid evaluation ictal onset was nonfocal in four patients in the first group (10%) and in two patients (28.5%) in the second group. One patient in the third (nonlesional) group was excluded because of incomplete data. In the remainder ($n = 18$), SDE ictal onset was multifocal or diffuse in 5 (27.8%) and focal in 13 (72.2%). Focality on SDE was positively correlated with higher noninvasive scores in the nonlesional patient group (χ^2 test, $P < 0.025$). Bayesian predictors in this group were highest for concordance between the interictal and ictal scalp EEG (likelihood ratio = 3.85). Considered separately, interictal and ictal EEG were of equivalent predictive value (likelihood ratio = 2.3 and 2.1, respectively). Metabolic imaging was the least useful modality.

Conclusions: (1) Diffuse or multifocal ictal onsets on SDE are almost three times as likely in nonlesional patients as in those with a single definite MRI brain lesion. (ii) The noninvasive data of children with nonlesional brain MRI may be summarized by a score that rewards localizing

information and intermodality concordance: low-scoring patients are more likely to exhibit diffuse or multifocal ictal onset on subsequent SDE. (iii) Bayesian likelihood ratios predictive of ictal focality on SDE are highly favorable for concordant scalp interictal-ictal EEG combinations. (iv) Decision-theoretic methods of this type may find use in the selection of nonlesional pediatric presurgical candidates offered SDE.

Keywords

Subdural grid; Pediatric epilepsy surgery; Concordance; Bayes theorem

Subdural grid evaluation (SDE) is an important, although highly invasive, diagnostic tool in the presurgical investigation of refractory focal epilepsy in children. The two principal reasons for SDE are to precisely localize the ictal onset zone and to perform electrical stimulation mapping to delineate eloquent cortex for surgical planning (Jayakar, 1999). Subdural grid evaluation is usually carried out after noninvasive tests have failed to localize the putative epileptogenic zone with sufficient clarity or if the epileptogenic zone seems too proximate to eloquent cortex. Failure to identify the epileptogenic zone is usually not a problem in the setting of a single relevant MRI-visible brain lesion; SDE performed in such patients is usually for eloquent cortex mapping or to precisely delineate the margins of resection that are already approximately known. A nonlesional MRI scan is the more challenging indication for SDE. Physicians and patients alike expect SDE to eventually lead to successful surgical resection, but in a small but significant minority of patients, the expectation is not met and the patient denied therapeutic resective surgery. Several case series in children and adults have documented the incidence of such an evidently undesirable “no-resection” outcome after SDE (Adelson et al., 1995; Henry et al., 1999; Kalamangalam et al., 2009; Pestana Knight, 2011). An important, but not the sole, reason for a no-resection outcome is failure to localize the ictal onset zone (i.e., seizures appearing of diffuse or multifocal onset on subdural EEG).

The purpose of this study was to understand the reasons for a nonlocalizing SDE in patients with normal MRIs. In particular, we asked whether such an SDE outcome was already implicit in the noninvasive data; that is, whether the noninvasive data foretold the subsequent (ostensibly unexpected) nonfocal SDE. Our approach in this pediatric surgical cohort parallels the motivation and methods of a previously published study in adult patients (Kalamangalam et al., 2009), using essentially the same methodology.

METHODS

This is a *post hoc* analysis of a cohort of 66 consecutive children aged 18 years and younger with refractory focal epilepsy who underwent SDE at Cleveland Clinic over a 7-year period (1997 to 2004). The demographic, clinical, and investigational data of this patient group were previously described by Pestana Knight et al. (2011). With respect to structural neuroimaging, 40 (60.6%) patients had a single MRI brain lesion, 7 (10.6%) had bilateral or diffuse MRI changes, and 19 (28.8%) were nonlesional. This work principally concerns the latter set of nonlesional patients. One patient’s data in that group were incomplete, yielding a final total of 18 patients ($n = 18$) who were further studied. Electrode placements were

performed with arrays of varying sizes, with commonly used sizes being 8×8 (64 contacts), 4×6 (24 contacts), 4×4 (16 contacts), 2×6 (12 contacts), and 1×6 (6 contacts). Interelectrode distance was 1 cm, center to center. The number of arrays varied from 4 to 7; total numbers of contacts varied from 78 to 153, with an average of 118. Placement of electrodes was targeted to cover brain areas harboring the putative epileptogenic zone, as suggested by the combination of the noninvasive evidence. In general, electrode placements were biased toward more, rather than less, numbers of contacts. For suspected anterior epilepsies, dorsolateral coverage was achieved densely with contiguous grids over the frontal and anterior temporal surfaces; for suspected posterior epilepsies, the postcentral parietal and posterior temporal areas were covered similarly. The mesial brain surfaces in these cases were sampled with multiple interhemispheric strips and/or depth electrodes that travel through the convexity in a coronal plane. The inferior brain surface was sampled with multiple strips. Suspected limbic epilepsies always received orbitofrontal coverage with grids.

Following the methods of a previously studied group of adult presurgical epilepsy patients (Kalamangalam et al., 2009), we formalized the “evidence” provided by the noninvasive data as favoring a focal, as opposed to a nonfocal, ictal onset on subsequent SDE, using two different approaches.

Approach 1

A hierarchical “score” summed up positive evidence equally from all components of the noninvasive data. The method considered the interictal EEG, ictal EEG, and metabolic imaging (positron emission tomography [PET] and/or single-photon emission computed tomography [SPECT]) as follows:

Step 1: Interictal EEG. Localizing (regional) location—Score 1; no spikes, multiregional (>2 spike populations in nonadjacent brain lobes), bihemispheric, or generalized spikes—Score 0.

Step 2: Ictal EEG. Localizing (regional)—Score 1; lateralized, generalized, nonlocalizable, or no EEG change—Score 0.

Step 3: Metabolic Imaging. Ictal SPECT or interictal PET, using the modality of greater score. Regionally specific metabolic or blood flow change—Score 1; normal or nonlateralizing findings—Score 0.

Step 4: Concordance Reward. Agreement between interictal and ictal EEG—Score 1 (0 otherwise); agreement between either PET or SPECT with ictal or interictal EEG—Score 1 (0 otherwise).

Thus, the maximum score of 5 reflected regionally specific change in the interictal and ictal EEG and concordance between either of these (or both) with regionally specific PET or SPECT change. To illustrate, a patient with truly generalized epilepsy would receive successive scores of 0 (generalized ictal EEG), 0 (generalized spikes), and 0 (nonfocal PET and SPECT), yielding a total score of 0. In contrast, a patient with right temporal lobe epilepsy might receive a perfect 5, comprising 1 (right temporal ictal EEG), 1 (right temporal spikes), and 1 (either ictal SPECT or interictal PET showing right temporal

change), with 2 additional concordance points. The scoring system was applied to each patient in the nonlesional group ($n = 18$) (Table 1). Our hypothesis—reflecting clinical heuristic—was that those with focal ictal subdural EEGs would have higher scores on the 0 to 5 scale than those with diffuse or multifocal patterns (equivalently, that noninvasive scores would be positively correlated with SDE outcome—low scorers with low concordance being nonfocal and high scorers with high concordance being focal).

Approach 2

We addressed the diagnostic “worth” accorded to any one test and combinations of tests. Table 2 displays the data broken down by each of the three individual noninvasive tests and their four combinations. The first three horizontal panels pertain to the focality (or not) of individual tests; the subsequent four panels represent test combinations (concordant or not). Columns index the corresponding invasive SDE findings (focal or nonfocal ictal onset), with the rightmost column of likelihood ratios discussed later. Table 2 was constructed by going over the Table 1 data for each patient, noting the result of an individual test and grouping it by that patient’s eventual SDE result. The sum of the integer values in the boxes pertaining to an individual test (or particular combination of tests) is 18, the aggregate of all possible outcomes for any one test applied to the whole group. Parsing the data in this manner allowed for the calculation of Bayesian conditional probabilities and likelihood ratios (see below).

RESULTS

Overall, SDE was “successful” (i.e., yielded focal ictal onset) in 54 of 65 patients (83.1%); in the remainder (11 of 65 = 16.9%), it was unsuccessful (multifocal or diffuse ictal EEG onset). However, in the 40 patients with a single definite MRI lesion, only 4 patients (10%) had an unsuccessful outcome. By contrast, SDE was unsuccessful in 5 of 18 nonlesional patients (27.8%)—a close to three-fold difference. Because of the small number of patients ($n = 7$) and their intrinsic complexity, those with bilateral or diffuse imaging changes were not considered further.

Table 3 displays the SDE outcomes (localizing or nonlocalizing ictal onset) versus the noninvasive scores of all 18 nonlesional patients. The term “nonlocalizing” included both truly diffuse ictal EEG patterns and patterns of discrete ictal onsets over multiple brain lobes. No non-invasive scores of 2 or 4 were obtained in any case, so the columns only document the instances of score values 1, 3, and 5. For this 2×3 contingency table with $df = 2$, we computed $\chi^2 = 7.48$ (Kirkwood, 1988), confirming our hypothesis at $P < 0.025$. At the individual level, we noted that there was a single instance among 11 of a high scorer of 5 turning out to be nonfocal on subsequent SDE, but both individuals with unit scores had nonfocal SDEs. Middle scorers (five individuals with score 3) were split between the two SDE outcome groups.

Our second approach used Bayesian probabilistic reasoning to estimate the diagnostic worth of individual investigations in numerical terms. Such numbers are useful for cross-modality comparison: for instance, faced with a localizing PET scan and a localizing, but discordant, interictal EEG, which entity should the clinician believe?

With the notation

n = total number of nonlesional patients = 18

n_1 = number of such patients with nonlocalizing SDE = 5, and

n_2 = number of such patients with localizing SDE = 13,

the overall probability of a patient having a localizing SDE was

$$P(F^+) = \frac{n_2}{n} = \frac{13}{18} \approx 0.72,$$

and the overall probability of a nonlocalizing SDE was

$$P(F^-) = 1 - P(F^+) \approx 0.28.$$

Here P denotes probability, the letter F is shorthand for focal, and the suffixes $+$ and $-$ have their intuitive meanings. The corresponding *odds* of a random patient having a positive (focal) SDE is defined as the ratio

$$\frac{P(F^+)}{P(F^-)} = \frac{0.72}{0.28} = 2.57.$$

Thus, at baseline the odds were 2.57 to 1 in favor of obtaining a positive SDE in our cohort. The further Bayesian question of how the arrival of successive pieces of evidence from the noninvasive tests improved, or degraded, the baseline odds required *conditional* probabilities that had the form $P(A|B)$: the probability of event A , *given* B . For example, the clinician is interested in the conditional probability of a localizing (positive) invasive EEG, given a focal (positive) interictal scalp EEG, that is, the numerical value of the symbolic quantity $P(F^+ | \text{iiEEG}^+)$. Conditional probabilities may be combined to construct likelihood ratios (LRs), connecting pretest and posttest odds via Bayes Theorem (Yates and Goodman, 1999). Likelihood ratios encapsulate the upgrading or degrading effect of a test on the pretest odds: values greater than unity upgrade, those lower than unity degrade, and values of exactly unity indicate the test adds no information to the pre-existing odds. From Table 2, LRs for each of the noninvasive tests and their combinations were:

LR (interictal EEG):

$$\frac{P(\text{iiEEG}^+ | F^+)}{P(\text{iiEEG}^+ | F^-)} = \frac{12 / 13}{2 / 5} \approx 2.31; \quad (\text{Case 1})$$

LR (ictal EEG):

$$\frac{P(\text{iiEEG}^+ | F^+)}{P(\text{iiEEG}^+ | F^-)} = \frac{11 / 13}{2 / 5} \approx 2.11; \quad (\text{Case II})$$

LR (PET/SPECT):

$$\frac{P(\text{PETSPECT} + | F +)}{P(\text{PETSPECT} + | F -)} = \frac{13 / 13}{5 / 5} = 1; \quad (\text{Case III})$$

LR (concordant interictal and ictal EEG):

$$\frac{P(\text{ii / iEEG} + | F +)}{P(\text{ii / iEEG} + | F -)} = \frac{10 / 13}{1 / 5} \approx 3.85; \quad (\text{Case IV})$$

LR (concordant interictal EEG and PET/SPECT):

$$\frac{P(\text{iiEEGPETSPECT} + | F +)}{P(\text{iiEEGPETSPECT} + | F -)} = \frac{12 / 13}{2 / 5} \approx 2.31 \quad (\text{Case V})$$

LR (concordant ictal EEG and PET/SPECT):

$$\frac{P(\text{iEEGPETSPECT} + | F +)}{P(\text{iEEGPETSPECT} + | F -)} = \frac{11 / 13}{2 / 5} \approx 2.11; \quad (\text{Case VI})$$

LR (all modalities concordant):

$$\frac{P(\text{ALL} + | F +)}{P(\text{ALL} + | F -)} = \frac{9 / 13}{1 / 5} \approx 3.46. \quad (\text{Case VII})$$

Taken in sequence, we observe that the interictal and ictal EEG (Cases I and II) were roughly equivalent on their influence on the previous odds: a localizing interictal or ictal EEG increased the odds of a successful SDE more than two-fold (LR = 2.31 and 2.11, respectively). Case IV demonstrated the powerful synergy of a concordant interictal and ictal EEG combination: the odds were virtually quadrupled (LR = 3.85). However, PET or SPECT (Case III) did nothing to alter the odds (LR = 1), and using those modalities in concordance with interictal or ictal EEG (Cases IV and V) yielded no improvement beyond the EEG alone. Finally, as one would expect, complete concordance of all modalities (Case VII) also yielded a high LR.

DISCUSSION

Epilepsy surgery in children remains a significantly multidisciplinary effort. Surgical candidacy is suggested by the detailed seizure history, but formal presurgical work-up is increasingly a multimodality approach. At minimum, the latter involves high-definition MRI and metabolic cranial imaging, in addition to electroclinical data (interictal and ictal EEG by video telemetry). Invasive studies, such as SDE, may follow in selected patients for better defining the ictal onset zone and delineating eloquent cortex. Despite SDE and the battery of preceding noninvasive investigations, a significant minority of children are denied resective surgery after SDE. A no-resection outcome after SDE may ensue for a variety of reasons

(Pestana Knight et al., 2011), but an important one is failure to identify the ictal onset zone with precision. The present study asked whether such failure could have been reasonably anticipated in advance, thus sparing the patient of the medical, economic, and psychosocial costs of a superfluous craniotomy.

Of the 66 patients who underwent SDE over the study period, we restricted our investigation to the subset that comprised 18 patients with nonlesional MRI scans, for three reasons. First, SDE is usually not pursued for patients with a single relevant MRI lesion; the noninvasive data suffices for surgical planning. Second, as our data demonstrate, SDE in lesional epilepsies is associated with a much higher degree of success than in nonlesional syndromes. Thus, there is less concern for SDE failure. Finally, it may be reasonable to offer resective surgery in the setting of a lesion even when the EEG is discordant—effectively targeting the MRI lesion alone and ignoring the electroclinical data (Wyllie et al., 2007). Conversely, the remainder of the noninvasive presurgical work-up (EEG, metabolic imaging, etc.) assumes added importance in nonlesional patients, the main subject group of this study. While we considered the usual modalities (EEG and metabolic imaging), advanced techniques, such as magnetoencephalography, diffusion tensor tractography, voxel-based morphometry, MR spectroscopy, and EEG-fMRI, (Richardson, 2010) will eventually become more widely available, adding to the complexity of the data considered in the context of individual patients. The clinician then faces the problem of integration of the results of multiple modalities with regard to the unknown epileptogenic zone. Current clinical practice follows the simplistic notion of “concordance” (Diehl and Lueders, 2000; Jayakar et al., 2008): essentially the rule that the greater the degree of agreement between the modalities, the greater the chance of a unitary epileptogenic zone with focal ictal onset. Viewed in this manner, the construction of our score did no more than formalize concordance by assigning numbers to the results of tests. We weighted the modalities of the interictal EEG, ictal EEG, and metabolic imaging equally, and rewarded intermodality concordance. Admittedly, our simple scoring scheme was only one of many possibilities. For instance, the modalities could have been weighted unevenly, and other factors such as lateralizing signs during seizures could have been incorporated. Nevertheless, significant segregation of high scorers with focal SDE and low scorers with nonfocal SDE were clearly demonstrated.

Our second analytic path took a more sophisticated view of the data. The question here was not so much what the data for any one patient demonstrated in aggregate, but what the incremental value of each modality was in determining subsequent focality on SDE. In our view, such an approach has greater general validity than aggregate scores. For instance, each modality (interictal EEG, PET, etc.) is naturally associated with a certain sensitivity and specificity (which may be in turn determined by local factors such as machine specifics and personnel expertise), and thus has a varying influence on determining SDE outcome. The clinician must then simultaneously assess multiple modalities of varying reliability, somehow prioritize one modality over another, and accurately assess the implications of intermodality concordance or discordance. A Bayesian approach using conditional probabilities and likelihood ratios is a natural quantitative framework for such a question (Kalamangalam et al., 2009). In essence, the question asked of a particular modality (or a combination of modalities) is to what extent does a positive result predict subsequent success on SDE? Our results suggested that both focal interictal and ictal EEG, considered

in isolation, were strong predictors of successful SDE outcome, doubling the odds (LR = 2.31 and 2.11, respectively). Concordance between the interictal and ictal EEG was however an even stronger predictor, virtually quadrupling the odds (LR = 3.85). This observation, in our view, vindicates the continuing indispensable role of scalp EEG in the presurgical evaluation of focal epilepsy: essentially, in a nonlesional patient with focal epilepsy, a concordant interictal/ictal EEG virtually guarantees success on subsequent SDE. More surprising was the neutral role played by metabolic imaging with PET and SPECT considered in unison (LR = 1), in seeming contradiction to larger pediatric epilepsy studies (Juhasz et al., 2001; Kumar et al., 2010). Although all our patients received PET, not all received SPECT; in an attempt to use the “best” data for the score, we chose the modality with the greater score, recognizing that PET and SPECT measure different brain processes. A perfectly reasonable alternate scheme would consider each modality separately, accepting the incomplete data for SPECT. Doing so (Table 4) yields a PET LR = 1.4 and SPECT LR = 0.81. Thus, both modalities considered separately also yield LRs close to unity, although PET by itself weakly enhances the previous odds. SPECT seems to degrade the previous odds, but the incomplete data make this a more tenuous conclusion. The distribution of data in Table 4 suggests why the LRs of these modalities are so noncommittal: although both have reasonable sensitivities, they both lack sufficient specificity, with relatively large numbers of false positives. The reasons for the latter, in turn, may be one or more of reporting bias in the setting of thresholds, timing of imaging in relation to the most recent seizure, the type of immediate previous seizure (e.g., partial or with secondary generalization), and so on, and are worthy of a separate investigation. Finally, complete concordance (LR = 3.46) was also associated with a high odds of SDE success.

We conclude that simple formal analytic methods such as those used here have great potential to aid the clinical decision-making process. The need for decision-theoretic formalisms that use probabilities will only increase as ever more investigative modalities are brought to bear on the determination of surgical candidacy for refractory focal epilepsy.

REFERENCES

- Adelson PD, Black PM, Madsen JR, et al. Use of subdural grids and strip electrodes to identify a seizure focus in children. *Pediatr Neurosurg* 1995;22:174–180. [PubMed: 7619717]
- Diehl B, Lueders HO Temporal lobe epilepsy: when are invasive recordings needed? *Epilepsia* 2000;41(suppl 3):S61–S74.
- Henry TR, Ross DA, Schuh LA, Drury I Indications and outcome of ictal recording with intracerebral and subdural electrodes in refractory complex partial seizures. *J Clin Neurophysiol* 1999;16:426–438. [PubMed: 10576225]
- Jayakar P Invasive EEG monitoring in children: when, where, and what? *J Clin Neurophysiol* 1999;16, 408–418. [PubMed: 10576223]
- Jayakar P, Dunoyer C, Dean P, et al. Epilepsy surgery in patients with normal or nonfocal MRI scans: integrative strategies offer long-term seizure relief. *Epilepsia* 2008;49:758–764. [PubMed: 18266748]
- Juhasz C, Chugani DC, Muzik O, et al. Relationship of flumazenil and glucose PET abnormalities to neocortical epilepsy surgery outcome. *Neurology* 2001;56:1650–1658. [PubMed: 11425929]
- Kalamangalam GP, Morris HH III, Mani J, et al. Noninvasive correlates of subdural grid electrographic outcome. *J Clin Neurophysiol* 2009;26:333–341. [PubMed: 20168131]
- Kirkwood BR Essentials of medical statistics. Oxford: Blackwell Science, 1988.

- Kumar A, Juhasz C, Asano E, et al. Objective detection of epileptic foci by 18F-FDG PET in children undergoing epilepsy surgery. *J Nucl Med* 2010;51:1901–1907. [PubMed: 21078805]
- Pestana Knight EM, Loddenkemper T, Lachhwani D, et al. Outcome of no resection after long-term subdural electroencephalography evaluation in children with epilepsy. *J Neurosurg Pediatr* 2011;8:269–278. [PubMed: 21882919]
- Richardson M Current themes in neuroimaging of epilepsy: brain networks, dynamic phenomena, and clinical relevance. *Clin Neurophysiol* 2010;121:1153–1175. [PubMed: 20185365]
- Wyllie E, Lachhwani DK, Gupta A, et al. Successful surgery for epilepsy due to early brain lesions despite generalized EEG findings. *Neurology* 2007;69:389–397. [PubMed: 17646632]
- Yates RD, Goodman DJ Experiments, Models and Probabilities Probability and Stochastic processes. New York: John Wiley & Sons, 1999.

TABLE 1.

Summary of Investigational Characteristics, Scored as Described in Text, of the Patients With Nonlesional Brain MRI (n = 18)

Patient	Age/Sex	Interictal Spike Localization	Ictal EEG Localization	Ictal SPECT	Interictal PET	Concordance Score	Total Score	Subdural Ictal EEG Onset
1	16/F	Generalized, max L temporoparietal (0)	L temporoparietal (1)	NA (0)	L frontotemporal (1)	1	3	Nonlocalizing
2	16/F	Vertex/L paracentral (1)	L frontocentral (1)	Bilateral frontal (0)	L frontal & L insula (1)	2	5	Localizing (L medial frontal)
3	9/M	Multiregional, R and L hemispheres (0)	Rt hemisphere or nonlocalizable (0)	R frontal (1)	Bifrontal maximum R (1)	0	1	Nonlocalizing (R hemisphere multiregional)
4	11/M	R frontocentral (1)	R frontocentral (1)	NA (0)	R frontoparietal (1)	2	5	Localizing (R peritrolandic)
5	13/M	Generalized, maximum vertex (1)	Generalized, maximum vertex (1)	R frontal (1)	R frontal (1)	2	5	Localizing (R superior frontal)
6	16/F	Bitemporal, R >> L (1)	R hemisphere, or R temporal, or nonlocalizable (0)	R temporal (1)	R frontotemporal (1)	1	3	Localizing (R orbitofrontal)
7	3/F	L frontocentral (1)	L frontocentral (1)	L frontal (1)	Nonlateralizing (0)	2	5	Nonlocalizing
8	12/F	Vertex and lateralized left hemisphere (1)	Nonlocalizable (0)	L frontoparietal (1)	Nonlateralizing (0)	1	3	Nonlocalizing (L hemisphere multiregional)
9	6/F	Bifrontal, independent (0)	L frontal (1)	Anterior vertex (1)	Nonlateralizing (0)	1	3	Localizing (L orbitofrontal)
10	17/M	L frontotemporal (1)	L frontal (1)	L anteromesial frontal (1)	L anterior frontal (1)	2	5	Localizing (L anterior frontal)
11	11/F	R centrottemporal (1)	R temporal (1)	R parietal > R insula and R temporal (1)	R temporal > R parietal (1)	2	5	Localizing (R temporoparietal)
12	16/M	No spikes (0)	R hemisphere (0)	NA (0)	R temporal (1)	0	1	Nonlocalizing (R hemisphere multiregional)
13	1/M	L frontocentral (1)	Vertex (1)	R insula/midfrontal (1)	Nonlateralizing (0)	2	5	Localizing (R lateral and medial frontal)
14	14/F	L temporal (1)	L temporal (1)	L temporal (1)	L anterior temporal (1)	2	5	Localizing (L lateral temporal)
15	17/F	L temporal (1)	L or R temporal (1)	NA (0)	L temporal (1)	2	5	Localizing (L lateral temporal)
16	10/M	R hemispheric, maximum centroparietotemporal (1)	R hemisphere (0)	R temporoparietal and R frontal (1)	R temporoparietal (1)	1	3	Localizing (R anterolateral and medial frontal)

Patient	Age/Sex	Interictal Spike Localization	Ictal EEG Localization	Ictal SPECT	Interictal PET	Concordance Score	Total Score	Subdural Ictal EEG Onset
17	17/M	L temporal (1)	L temporal (1)	Nonlateralizing (0)	L temporal > L parietal and inferior frontal (1)	2	5	Localizing (L lateral temporal)
18	8/M	L temporal (1)	L hemispheric, maximum frontotemporal (1)	L frontotemporoparietal (1)	L temporal > L parietal (1)	1	5	Localizing (L anterior temporal)

The rightmost column documents the electrographic outcome on subsequent SDE.

L, left; R, right; NA, not available (or not done).

TABLE 2.

Numbers of Patients Classified With Respect to the Results of Each Noninvasive Test and Individual Combinations, Indexed Also by Eventual Invasive Outcome

	Focal Subdural Ictal Onset		Nonfocal Subdural Ictal Onset		Likelihood Ratio
Interictal EEG (iEEG+): Localizing (score 1)	12	2	2	2.31	
Interictal EEG (iEEG-): nonlocalizing (score 0)	1	3	3		
Ictal EEG (iEEG+): Localizing (score 1)	11	2	2	2.11	
Ictal EEG (iEEG-): nonlocalizing (score 0)	2	3	3		
PET or SPECT (PETSPECT+): Localizing (score 1)	13	5	5	1	
PET or SPECT (PETSPECT-): nonlocalizing (score 0)	0	0	0		
Interictal and Ictal EEG concordant (ii/iEEG+)	10	1	1	3.85	
Interictal and Ictal EEG discordant (ii/iEEG-)	3	4	4		
Interictal EEG and PET/SPECT concordant (iiiEEGPETSPECT+)	12	2	2	2.31	
Interictal EEG and PET/SPECT discordant (iiiEEGPETSPECT-)	1	3	3		
Ictal EEG and PET/SPECT concordant (iEEGPETSPECT+)	11	2	2	2.11	
Ictal EEG and PET/SPECT discordant (iEEGPETSPECT-)	2	3	3		
All modalities concordant (ALL+)	9	1	1	3.46	
Two or more modalities discordant (ALL-)	4	4	4		

All data are extracted from Table 1. The sum of the integers in the boxes of each panel is 18, the total number of patients considered. Vertical sums in each table (along the second two columns) are 13 and 5, the number of patients with eventual focal, or nonfocal invasive EEG outcome. The grouping allows for computation of conditional probabilities and likelihood ratios used in Bayesian calculations. The latter are specified in the rightmost column for all positive localizing results of the respective noninvasive tests.

TABLE 3.

Numbers of Patients With Scores of 1, 3, or 5 Classified With Respect to Subsequent SDE Outcome (Nonfocal or Focal Ictal Onset)

	Score 1	Score 3	Score 5	Row Totals
Nonfocal SDE	2	2	1	5
Focal SDE	0	3	10	13
Column Totals	2	5	11	Grand total = 18

The raw numbers suggest segregation of the data with both patients with score 1 being nonfocal on SDE, and 10 of 11 patients with score 5 being focal on SDE. Application of the χ^2 test to this 2×3 contingency table with $df=2$ yielded $\chi^2 = 7.48$, corresponding to $P < 0.025$.

SDE, Subdural grid evaluation.

TABLE 4.
Numbers of Patients Classified With Respect to the Results of PET and SPECT Individually, Indexed Also by Eventual Invasive Outcome

	Focal	Subdural	Ictal	Onset	Nonfocal	Subdural	Ictal	Onset	Likelihood Ratio
PET (PET+): localizing				11			3		1.4
PET (PET-): nonlocalizing				2			2		
SPECT (SPECT+): localizing				9			3		0.81
SPECT (SPECT-): nonlocalizing				2			0		

All data extracted from Table 1. The sum of the integers in the boxes corresponding to PET is 18, the total number of patients considered; for SPECT, it is 14.