Surface Ictal Electroencephalographic Patterns in Frontal vs Temporal Lobe Epilepsy

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ABSTRACT: The effectiveness of long term EEG monitoring in the localization of the epileptic focus was studied in 37 patients with temporal lobe epilepsy comprising 190 recorded seizures, in 19 frontal lobe epileptic patients with 172 recorded seizures and in 12 additional patients which were classified as fronto-temporal. In the temporal lobe group, 49/190 seizures began focally (26%) and 20/190 seizures exhibited a regional onset (10%). In the frontal lobe group, only 21 out of 172 seizures (12%) had a focal ictal onset. 41/172 seizures began regionally (24%). In the fronto-temporal group, 31/55 seizures disclosed a focal EEG onset (57%). This study demonstrates that there is a two-fold increase in seizures beginning focally in the temporal lobe epilepsy group versus the frontal lobe group.

RÉSUMÉ: Caractéristiques à l'électroencéphalographie ictale de surface de l'épilepsie frontale vs temporale. L'efficacité du monitoring EEG prolongé dans la localisation des foyers épileptiques a été évaluée chez 37 patients avec épilepsie temporale (190 crises ont été enregistrées), 19 avec épilepsie frontale (172 crises enregistrées) et 12 avec crises classifiées fronto-temporales. Dans le groupe des épileptiques temporaux, 49/190 crises (26%) avaient un point de départ EEG focal et 20/190 avaient un début régional (10%). Dans le groupe des épilepsies frontales, seulement 21 des 172 crises enregistrées (12%) avaient un début focal, alors que 41 des 172 crises (24%) avaient un point de départ régional. Dans le groupe des patients fronto-temporaux, 31 des 55 crises (57%) ont été à début focal. Cette étude démontre que la proportion des crises à départ focal est deux fois supérieure chez les patients avec épilepsie temporale par rapport à ceux qui souffrent d'épilepsie frontale.

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This topic is hardly new to epileptologists who for years have attempted to predict the underlying brain pathophysiology from a remote current source based on the surface EEG. The practical and theoretical disadvantages of this approach have been all reviewed by other authors [1-3] and will not be discussed here. Rather some of the literature on surface EEG, primarily ictal, in frontal and temporal lobe epilepsy will be presented to point out differences of opinion and areas of controversy. Our data will be presented and then discussed with respect to previous studies and planning for surgical resection.

Nearly 30 years ago, Fegersten and Roger wrote, "In spite of the fact that human frontal lobes are being injured daily in motor car accidents, frontal lobe lesions producing epilepsy have received little attention."[4] This situation has been improved upon by well known publications such as those of Rasmussen[5,6] Ajmone-Marsan and collaborators,[7,8,10] Williamson et al.,[11-13] Quesney and collaborators,[3,14,15] Bancaud and collaborators,[16-19] the Cleveland Clinic group[20,20a] and by the Comprehensive Epilepsy Program of California.[21-23] Nevertheless, the basic understanding of the diagnosis, pathophysiology and management of this type of focal epilepsy does not approach the experience with temporal lobe epilepsy which is either more frequent or more intractable or both. Frontal lobe epilepsy appears to account for 15%[24] to 30%[13] of focal epilepsies. The remainder are generally ascribed to temporal lobe epilepsy although in one small series parietal seizures were equal in frequency to frontal seizures.[25] Recently, Delgado-Escueta[26] has published an algorithm for distinguishing temporal from frontal lobe complex partial seizures. The algorithim does not specify particular EEG characteristics common to one or the other. This issue will therefore be addressed in this chapter.

The interictal EEG is frequently of value in localizing the epileptic focus.[1,5,27-33a] However, the ability to record from inferior, mesial or mesial-basal structures is limited.[1-3] Some studies by the same authors above and others specifically question the use of the surface interictal EEG.[12,33-37] Intracranial recordings naturally improve the localizability of the epileptogenic zone.[2,8,10,38-42] The ictal EEG is felt to be the best non-invasive

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indicator of the epileptogenic zone but false localizations have been reported on surface EEG[31,43] and on depth ictal recordings[44] in the presence of large gliotic or tumorous lesions. Nevertheless, it is possible to record very focal interictal abnormalities in patients with diffuse intracranial[10] or extracranial onsets.[45] (Also see Figures 3-5 this paper).

Quesney, having reviewed these problems in detail[3,14,15] concluded that the large disparities between different groups' reports of interictal and ictal EEG discordance (5-33%) were likely due largely to differences in the methodology of interpretation of the EEG's. One study confirmed this by reporting extremely low interobserver agreement for all foci with respect to surface and even depth ictal EEG data.[43]

The above cited literature is dominated by reports on temporal lobe epilepsy. When one comes to the problem of distinguishing frontal from temporal lobe seizures there are no clearly defined EEG criteria. It is well known that rapid spread of ictal discharges occurs from temporal to frontal lobes or vice versa throughout the uncinate fasciculus or cingulum[45,46] making interpretation difficult. Frontal lobe foci may appear indistinguishable from primary generalized epilepsy with bilaterally synchronous spike and wave patterns.[16,46-51] To further complicate matters, Gastaut has noted that medial frontal lobe foci may appear with temporal EEG maxima,[52] which we have also noted.

Tables 1A and 1B were constructed from previous publications to show the range of data on localizability of surface EEG in temporal and frontal lobe epilepsy. They are not intended to be comprehensive. In temporal lobe epilepsy the interictal EEG was found to be focal or localizing in 30-55% of records, while ictal onsets were focal or localizing in 41-94% of records. In frontal lobe epilepsy the interictal EEG was focal or localizing in 13 to 72% with 4-100% of ictal records providing localizing information, showing the greater disagreement among investigators with regard to frontal than temporal lobe epilepsy.

Methods

Patients referred for evaluation of intractable seizures were classified according to: 1) their electroclinical manifestations as observed with CCTV-EEG ictal recordings, 2) corroborative neuroimaging (CT, MR, and FDG-PET scans), and 3) neuropsychological investigations, as temporal, frontal, frontal-temporal (or temporal-frontal) or frontal-parietal. Thirty-seven patients with temporal lobe seizures as verified by results of intracranial monitoring and/or surgical excision were studied. In this group, 190 seizures and 43 interictal EEG's were available for review. Nineteen patients were classified as having frontal lobe epilepsy. Twelve of these have undergone surgery while in 7 the localization is presumed on the basis of the presurgical evaluation as mentioned above. In these 19 frontal lobe patients, 172 seizures and 27 interictal EEG's have been reviewed. Twelve other patients fell into a temporal-frontal (n = 8) or frontal-temporal classification (n = 4). Seven of these have had intracranial

Table 1A: Localizing Value of Interictal and Ictal EEG in Focal Seizure Disorders (Temporal)

Author	Accuracy of Interictal EEG	Accuracy of Ictal EEG	Lobe	No. of Patients
Christodoulou, 1967	52% focal sphenoid spike	Not available	Presumed temporal	102
Theodore et al., 1983	40% focal or mainly focal 50% multifocal or bilateral 7% diffuse slow 8% normal	50% focal	Temporal	40
Spencer, et al., 1983	50% localized 14% lateralized 14% bilateral 16% falsely localized or noninformative	Not available	Mainly temporal	27 patients and EEGs
Spencer, et al., 1985	Not available	51-61% localizable	Temporal	27
Estimated by B.E. Swartz from Quesney et al., 1984 and Quesney & Gloor 1987	Not available	47% focal or regional 31% bilateral 22% uninformative	Temporal	148
King et al., 1986	Not available	41% localized at sphenoid	Temporal	12
Dodrill et al., 1986	31 single focus 39 mainly temporal 54 anterior to mid-temporal 35 lateralized 42 noninformative	Not available	Mainly temporal	75
Wyllie et al., 1987	60% focal	94% focal	Temporal	50
Risinger et al., 1988	Not available	52% focal sphenoidal 24% lateralized or nonsphenoid localized 24% other patterns	Temporal	110 patients 706 seizures

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recordings and /or surgery to establish the localization while 5 are presumptive. These two groups were combined for reasons discussed later. In this group, 75 seizures and 17 interictal EEG's were available for review. 21 seizures and 5 interictal EEG's were reviewed from the group of 5 patients with frontal-parietal foci.

All surface EEG's were recorded using 18-25 channels of silver/silver chloride or gold disk electrodes applied with colloidan according to the International 10-20 placement system. The interictal EEG's were 1 hour in duration, awake and asleep and usually included nasopharyngeal recordings. All ictal recordings had sphenoidal recordings. Additional electrodes, such as orbito-frontal, or placements in between the standard ones were used as deemed necessary. All EEG's were reviewed initially by a single board-certified electroencephalographer and later reviewed by three certified electroencephalographers in collaboration. Since the three reviewers have worked closely together for some years it was believed that attempts to co-verify each others readings with a blind design would necessarily be biased, so this was not done. Nearly all EEG's were independently reviewed by the principle author after the original interpretation was performed and any questions on interpretation were discussed amongst the three.

The EEG ictal onsets were defined as the following:

Table 1B: Localizing Value of Interictal and Ictal EEG in Focal Seizure Disorders (Frontal)

Author	Accuracy of Interictal EEG	Accuracy of Ictal EEG	Lobe	No. of Patients
Ludwig et al., 1975	30% focal (14% also had secondary bilateral synchrony) 35% regional 15% bilateral or lateral 15% no spikes	Not available	Frontal Lobe	14 cases (total 28 extra temporal patients)
Quesney et al., 1984	22.5% focal 40% regional 18% lateral 4.5% bilateral 9% normal	22% focal or regional* 11% lateral 37% bilateral 30% noninformative *30% focal with supraorbital or nasopharyngeal electrodes	Frontal Lobe	22 patients 302 seizures
Williamson et al., 1985	50% misleading 20% secondary bilateral synchrony 30% unavailable	70% obscured by artifact 30% (?) post-ictal generalized slowing	Frontal Lobe	10
Spencer et al., 1985	Not available	12-21% localizable	Frontal Lobe	7
Wyllie et al., 1987	40% focal frontal 30% focal fronto-parietal	100% localizable	Frontal Lobe	10
Quesney, 1987	13.5% focal 73% frontal central 13.5% unreliable	Not available ?	Frontal Lobe	?
Quesney & Gloor, 1988	Not available	22% focal or regional 11% lateral 37% bilateral 19% uninterpretable 11% no change	Frontal Lobe	16 patients 302 seizures
Morris et al., 1988	55% focal 36% normal 9% > focus	19% focal 19% lateralized 27% generalized 27% obscured 6% normal	Frontal Lobe	17
Fegersten and Roger, 1961	33% focal 33% regional 30% regional plus bilateral 13.5% focal 73% frontal central 13.5% unreliable	Not available ?	Frontal Lobe	30 patients and EEGs 10 seizures
Veilleux et al., 1990	46% lateralized 4% localized	96% diffuse onset	Frontal Lobe	23

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1. Focal — rhythmical spikes or sharp waves with phase reversals seen clearly at one electrode on bipolar recordings (Figure 1), or focal attenuation (Figure 2). The field could extend from one to three contiguous electrodes including sphenoidal. A fourth electrode could be included if it was between standard placements. An example of a focal ictal onset is seen in Figure 1.

2. Regional — rhythmical spikes, sharp or slow waves or attenuation arising within one lobe. A regional ictal onset is noted in Figure 3.

3. Lateral — rhythmical spike and wave or sharp waves or polyspikes, slowing, or attenuation confined to one side.

4. Bilateral — rhythmical sharp waves, spike and wave, polyspikes, or attenuation (low voltage fast activity) seen across both hemispheres.

In a previous publication, if a pattern which developed into a phase reversing spike or sharp wave at a sphenoid electrode occurred within 30 seconds, it was arbitrarily considered to be focal,[53] while others have stated that the sphenoidal pattern should appear at the beginning or within "a few seconds" of the clinical onset.[54] A previous study from our group of depth vs. sphenoidal patterns showed that frontal lobe seizures could present as a delayed sphenoidal focus.[55] This appears particularly problematic from cingular foci.[52] Our working definition of "onset" was the first to third seconds of electrographic change.

Similarly the interictal EEG's were classified as:

1. Focal — spikes or sharp waves at one to three contiguous electrodes with phase reversals at a single electrode, or focal polymorphic slow waves (Figures 4a, 5b).

2. Regional — spikes, sharp waves, polymorphic delta, rhythmic slowing seen in one lobe. Multifocal spikes within one lobe could be included.

3. Lateral — rhythmical or polymorphic slowing or multifocal spikes or sharp waves confined to one hemisphere.

4. Bilateral — general background slowing, bifrontal rhythmical delta, bilaterally synchronous spike and wave (Figures 4b, 5a) or sharp waves or multifocal bilateral sharp waves or spikes.

Results

Temporal Lobe Epilepsy

Of the 190 recorded seizures, 49 began focally (26%), 20 (10%) began as a regional pattern, 2 began laterally, 70 (47%) began with diffuse attenuation while 49 (26%) began with other bilateral patterns. The primary focus was a sphenoid electrode with or without surrounding anterior to mid-temporal involvement, in all but six seizures in which the focus was at T5.

In this study an additional 49 seizures did become focal at a sphenoid after beginning with another pattern. However, when we examined the distribution of time required for the initial pattern to change to a second pattern, we found that 76% had changed within 10 sec and another 16% changed by 20 sec. Thus, in most temporal lobe seizures the electrographic patterns had evolved in less than 15 sec with a mean of 8.4±6 sec (s.d.). and classifying the EEG as focal after delays of greater than 10 sec was not statistically justifiable. There were no seizures with a focal onset that appeared to be extra temporal.

Interictal EEG's from the temporal lobe patients showed that 17 patients of 32 had focal sharp waves or spikes on at least one EEG (53%). Two of 18 (11%) focal interictal EEGs showed spiking outside the temporal lobe.

Frontal Lobe Epilepsy

In the pure frontal group with 172 seizures only 21 or 12% had a focal ictal onset with another 14 becoming focal after a delay. No one electrode was favored over others with respect to this focality. 41 seizures began regionally (24%), 5 began as lateralized patterns (3%), and 61% began as bilateral slowing or as a generalized low voltage fast pattern. The ictal patterns evolved to another by 5 sec in 31% and by 10 sec in 81%. The mean time of pattern evolution was 8.5±6 sec (s.d.).

Forty-four percent of the patient's interictal EEG's had focal sharp waves or spikes on at least one EEG. One of these foci (11%) appeared to be within the temporal lobe.

Temporal-Frontal/Frontal-Temporal Epilepsy

These groups were combined because of the similarities in the EEG patterns. There were 55 seizures in the temporal-frontal group (TF), 31 of which began focally (57%), with 2 lateralized at onset (4%), and 40% began as bilateral slowing or diffuse attenuation (low voltage fast patterns). In the fronto-temporal (FT) group 10 of 20 (50%) began as a focal pattern with the other 10 beginning in a bilateral or diffuse fashion. Combining the two groups, a total of 54.5% began focally, 3% began as a lateralized pattern and 42.5% began in a diffuse or bilateral pattern at onset (n = 75). The mean time for one pattern to evolve to another was 6.5±3.1 (s.d.) sec. in this group. 48.5% had changed from the initial to a second pattern by 5 sec and 85% had done so by 10 sec. 25% had focal interictal spikes or sharp waves in the TF/FT group.

Frontal-Parietal Group

Five patients having 21 recorded seizures were in this group. 15 or 71% began as a focal pattern at C3-P3 or C3-Cz. The rest (29%, n = 6) began as bilateral spike and wave or attenuated patterns. 20% of the interictal EEG's had focal sharp waves or spikes in this group.

Differences in the Groups

A summary of these results is given in Tables 2a, 2b, and 3a & 3b and Figure 6. There is a two-fold increase in seizures beginning focally in the temporal lobe epilepsy group vs the frontal lobe group. Can we include those seizures which begin as diffuse attenuation or bilateral slowing and later become focal in the focal group? Using an analysis of variances we previously showed that in temporal lobe epilepsy, outcome was related to ictal onset type, with patients who had either focal or regional onsets showing better outcomes following temporal lobectomy compared to those with bilateral, lateral or diffuse attenuation onsets.[56] In addition, one of the patients with cingulate epilepsy had phase reversing sharp waves at a sphenoid electrode within seconds of the surface EEG seizure onset. Therefore we do not think it valid to include those patients whose seizures became focal after a diffuse plus bilateral onset amongst the focal group. Our past analysis supported the validity of combining regional and focal groups with respect to outcome.[56] The percentages of seizures beginning either focally or regionally are identical (36.5% and 36%, respectively) for frontal and temporal lobe seizures. Similarly, frontal and temporal groups show the same percentage of diffuse or bilateral onsets. Of interest is the fact that the TF/FP groups and the frontal-parietal groups have higher percentage of focal onsets than either frontal or temporal lobe seizures.

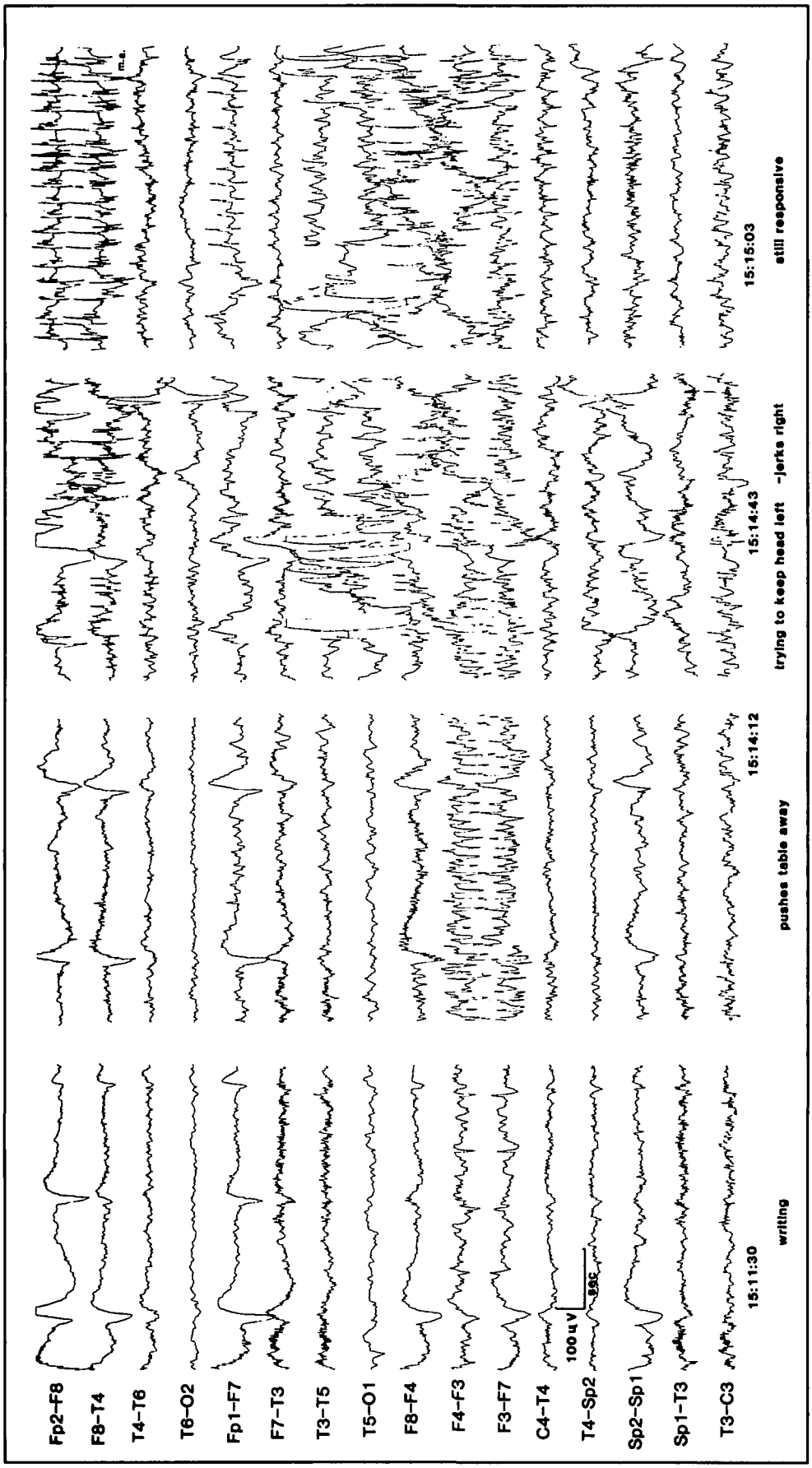

Figure 1 — A simple focal seizure beginning at F3 consisted of palpebral clonae. Within 2-3 minutes a complex partial seizure of the "M2e" type occurred, followed by generalization.

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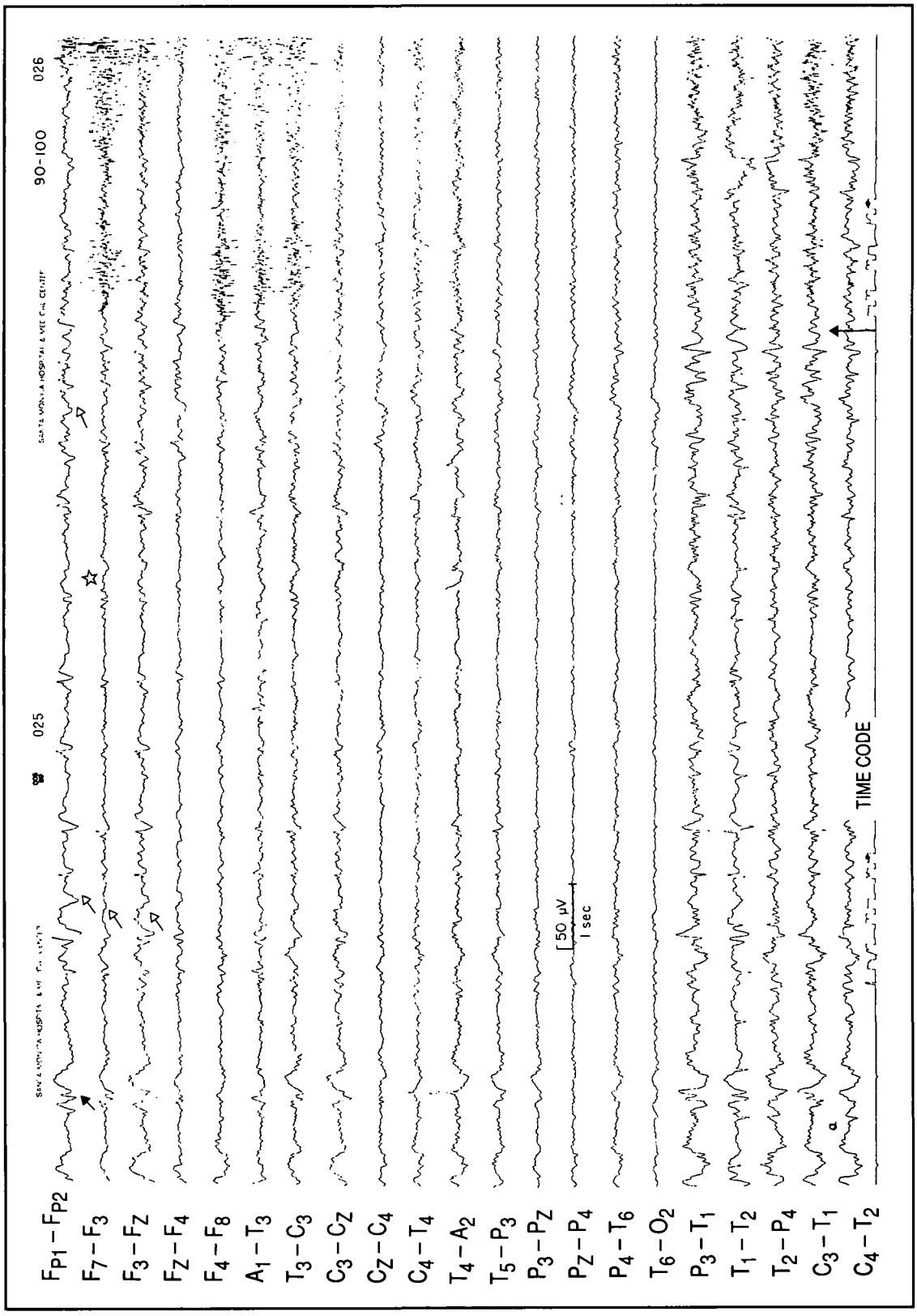

*Figure 2 — A left frontal interictal spike focus began increasing in frequency (closed arrow) followed by some rhythmic background slowing (open arrows) and a suggestion of low voltage fast activity at F7-F3 (*). At 13:31:50 (long arrow) a typical tonic drop attack occurred (extension of 3 limbs with right elevated), accompanied by a bifrontal low voltage fast pattern on EEG.*

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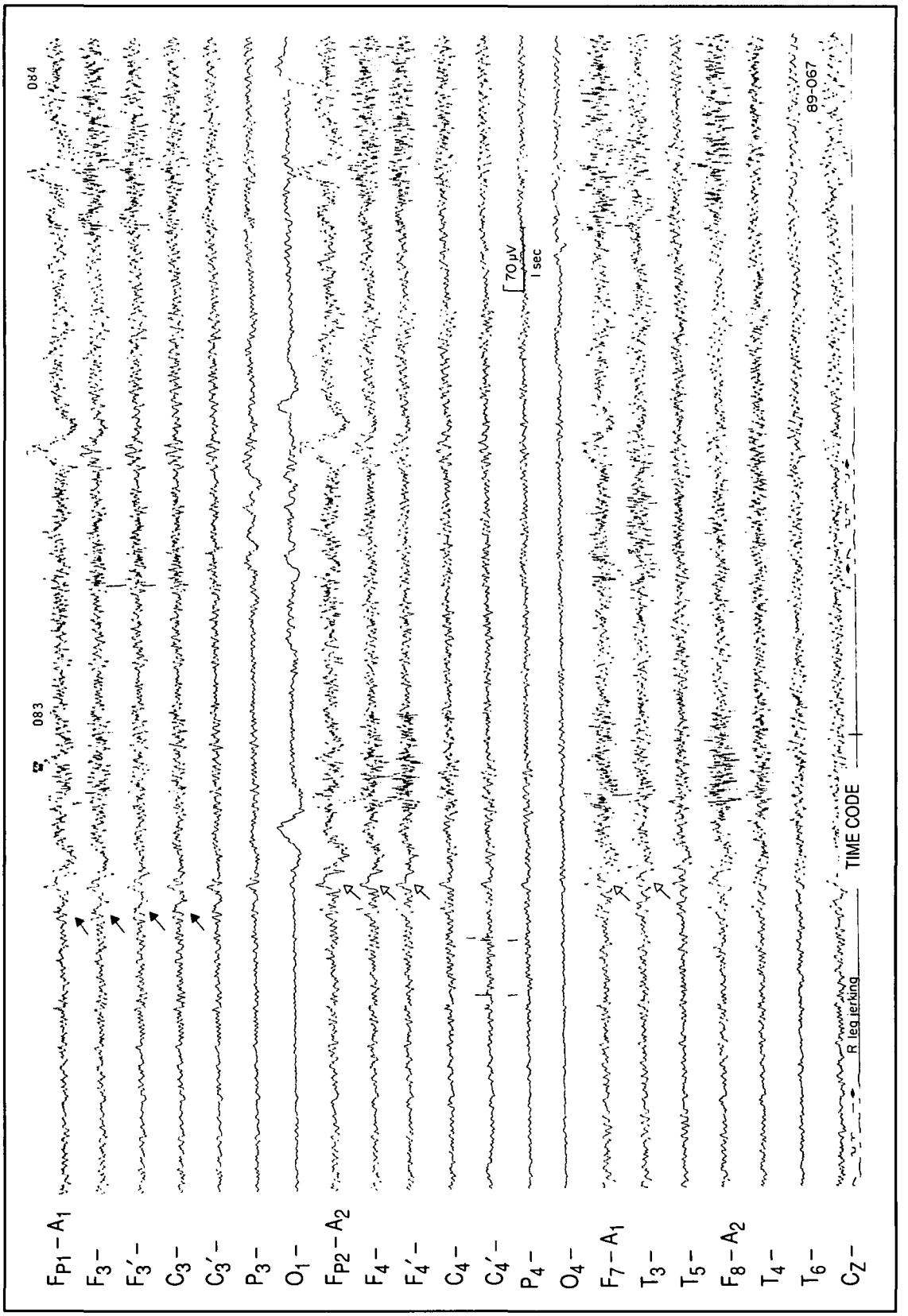

Figure 3 — Probable left medial frontal epilepsy. The patient has frequent attacks of right leg myoclonus or brief tonic spasms of the right leg, but with normal neuroimaging. A typical right leg jerking occurred in sleep, at the dark arrows when a triangular wave is seen in the left frontal leads. One-half sec later it appears in left temporal and right frontal leads (clear arrows). The jerking lasted only a few seconds but typically aroused the patient. The "prime" leads are placed midway between standard placements. The seizures were temporarily controlled with carbamazepine.

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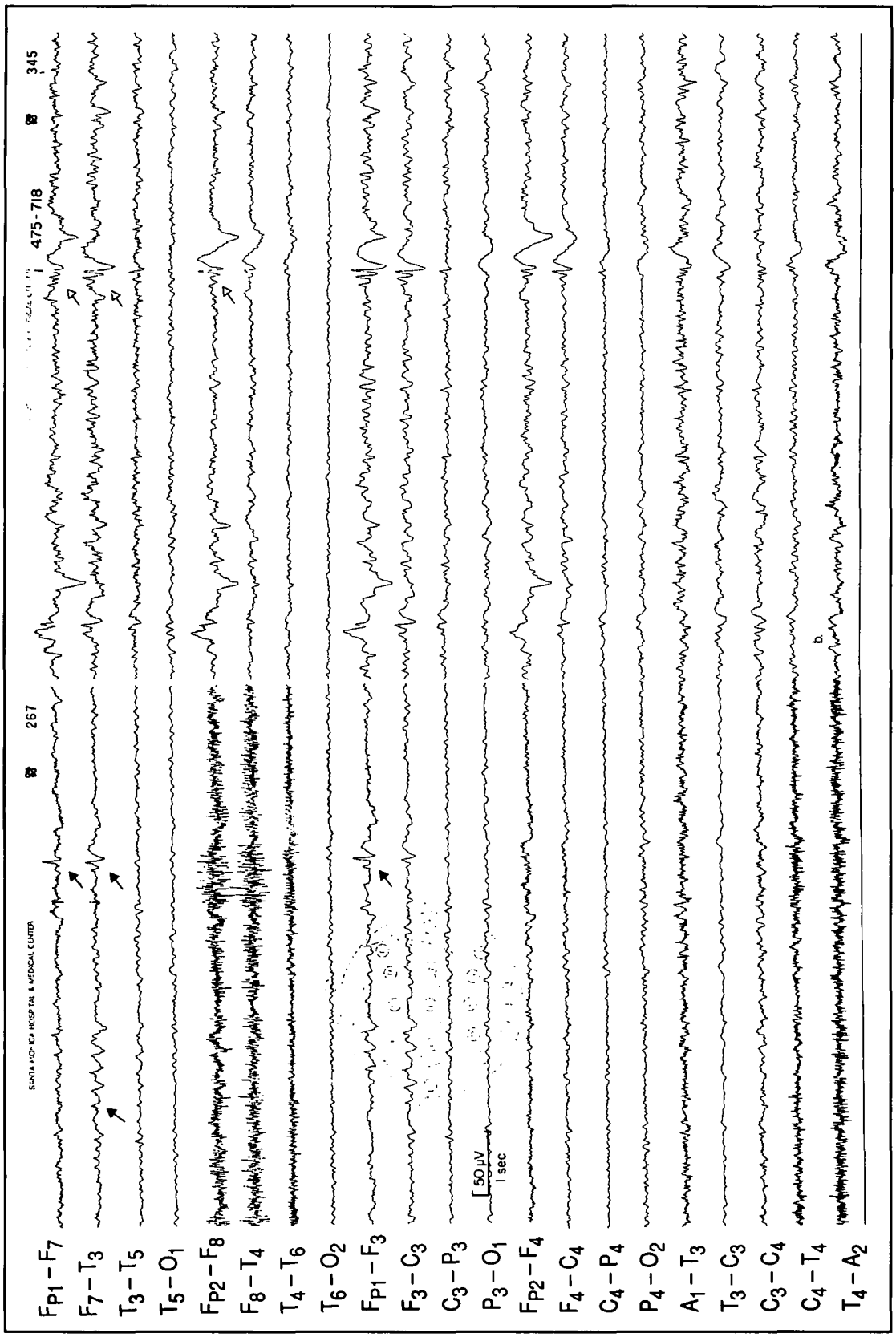

Figure 4a — An interictal spike and runs of sharply contoured 4 c/s waves are seen at Fpl, F7 and F3 (closed arrows). Same patient as in Figure 2. 4b) At right of page: in drowsiness, secondary bilateral synchrony becomes prominent (open arrows).

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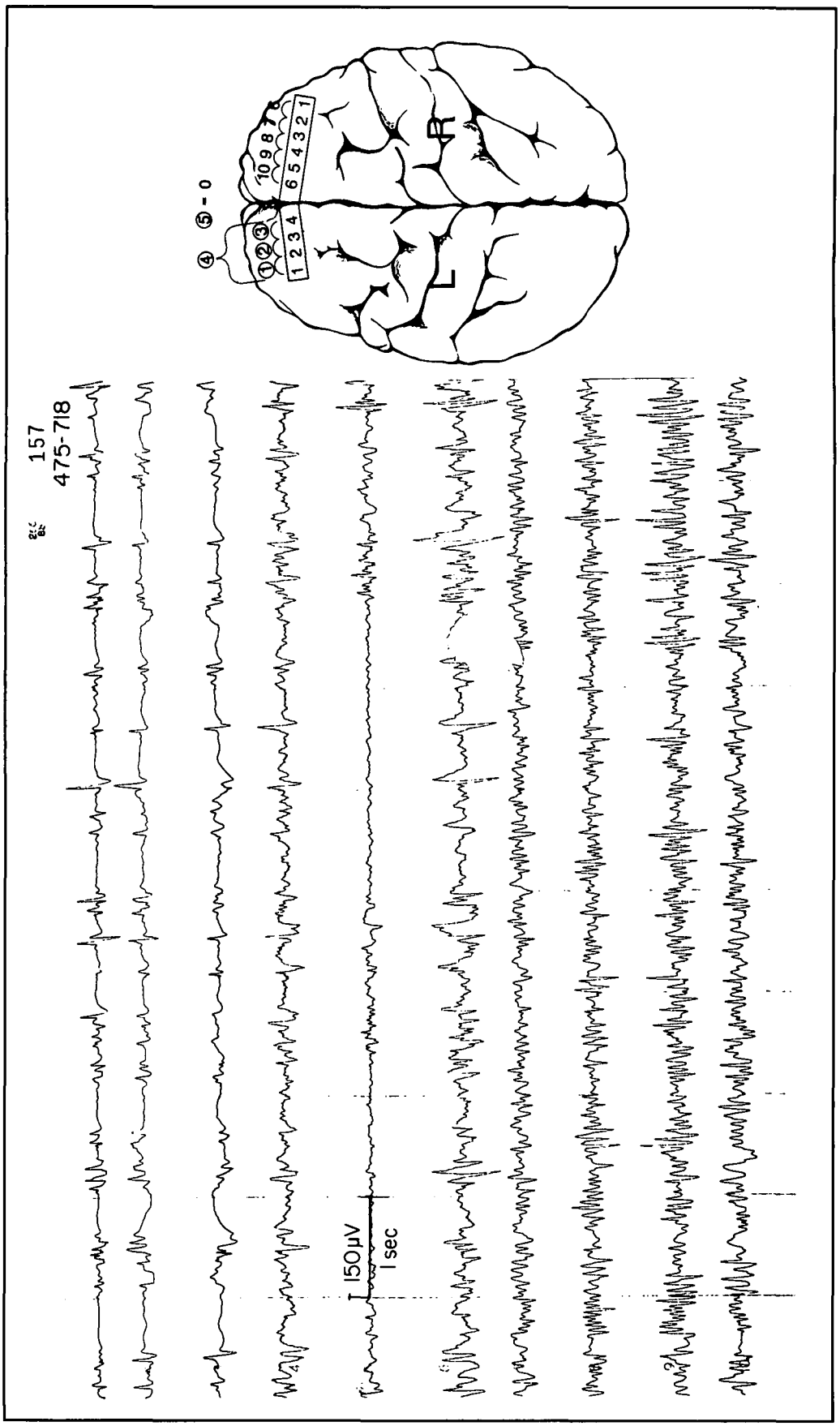

Figure 5a — At electrocorticography a frequent spike focus was seen at the left frontal region which frequently appeared at right frontal sites as well. The left-frontal background is depressed. Same patient as in Figures 3 and 4. 5b) After anterior 2/3 callosotomy, the left frontal spike persists but the right site has normal rhythms. Sensitivity below is for the left hemisphere, that above is for the right

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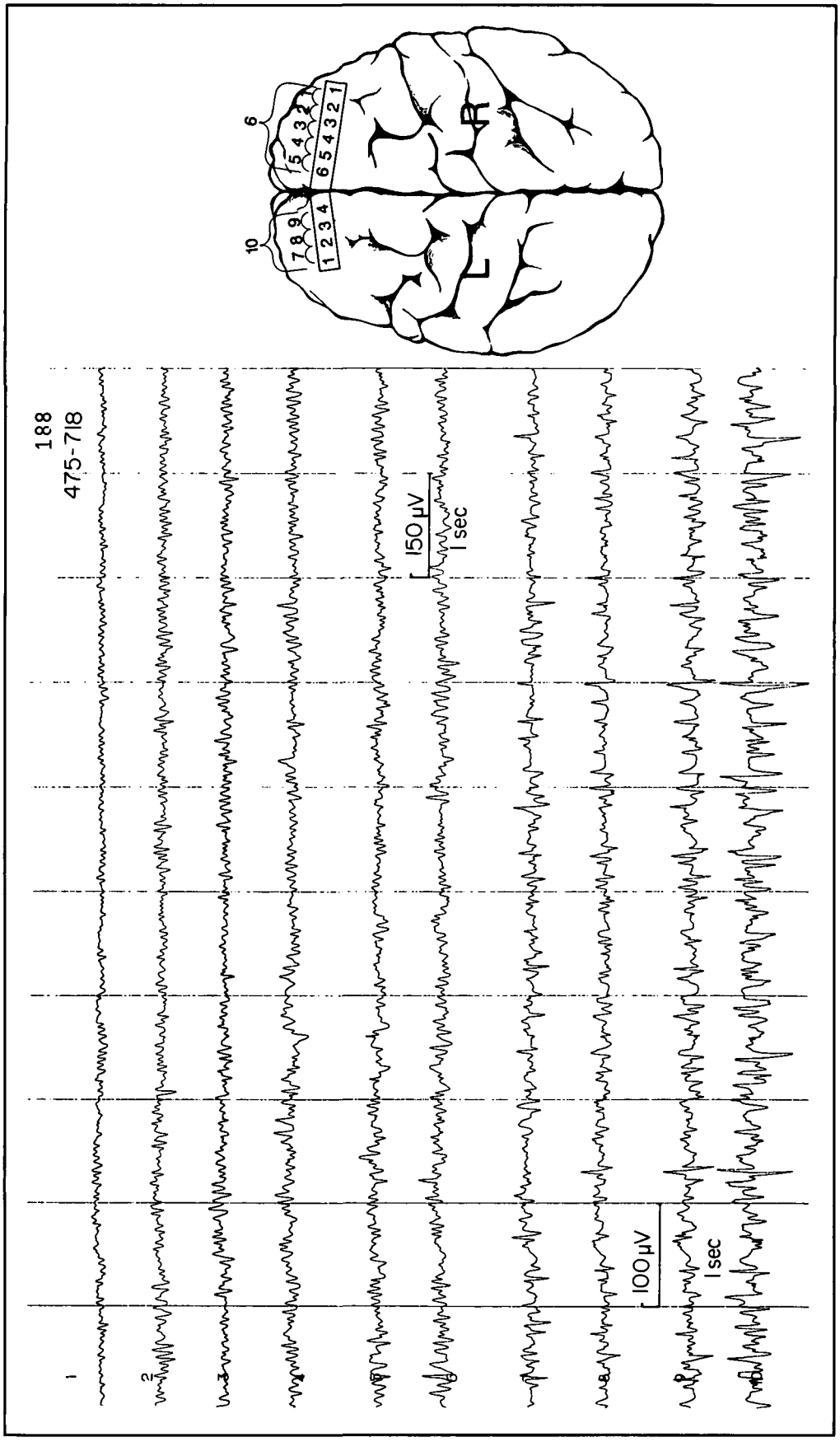

Figure 5B.

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If we combine seizures whose patterns became focal after a regional, lateral, bilateral or diffuse onset with the focal onset seizures our percentages are nearly identical to those published by Quesney[14,15] (Tables 1a, 1b, 2b).

There appears to be a greater percentage of focal interictal EEG's with temporal than with frontal, temporal/frontal - frontal/temporal, or frontal – parietal epilepsy when only one EEG was considered per patient. However, the ratio of accurate to inaccurate EEG's is the same for the frontal and temporal groups. Increasing the number of interictal EEG's per patient increased the incidence of patients with a focal EEG from 46.5% to 55% in the temporal group and from 33% to 53% in the frontal group.

Distribution of Onset Types and Times of Pattern Evolution

The interseizure variability of onset types within one patient has not been addressed to our knowledge. This interseizure variability may explain why, with extremely poor interobserver agreement on EEG interpretation in Spencer's study,[43] the EEG readers nevertheless had similar percentages of agreement between the proposed focus based on surface EEG as compared to the confirmed focus on depth recordings.

We recorded an average of 5.1 seizures per patient in the temporal lobe group with a mean of 1.8 onset types per subject. In the frontal lobe group there was a mean of 10 seizures per patient with 1.4 seizure onset types per patient. In the FT/TF

Table 2A: Electrographic Onsets in Focal Epilepsy

	Focal	Regional	Bilateral or Diffuse	Lateral	No. Seizures
Temporal	26%	10.5%	62.5%	1%	190
Frontal	12%	24%	61%	3%	173
TF/FT *	54.5%	0%	42.5%	3%	75
Fronto-parietal	71%	0%	29%	0%	21

*Temporal-frontal /Frontal-temporal

Table 2B: Electrographic Onsets in Focal Epilepsy

	Initially or Secondarily Focal	Regional	Bilateral or Diffuse	Lateral
Temporal	52%	6.8%	40%	1.2%
Frontal	20%	24%	53%	3%

Table 3A: Interictal EEG Patterns in Focal Seizures

	(% of EEG's)					
	Focal	Regional	Lateral	Bilateral or Diffuse	Normal	No. EEGs
Temporal	46.5%	23.25%	5%	23.25%	2%	43
Frontal	33%	18.5%	13.5%	33%	3%	27
TF/FT *	25%	27.5%	12.5%	25%	6%	17
Fronto-parietal	20%	20%	40%	20%	0%	5

*Temporal-frontal / Frontal-temporal

Table 3B

	Focal Correct	Focal Incorrect	No. EEGs
Temporal	18	2	43
Frontal	8	1	27
T-F/F-T *	3	1	17

*Temporal-frontal / Frontal-temporal

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group there was an average of 7.5 seizures recorded with 1.5 onset types per patient. We previously reported that post-surgical outcomes in temporal lobe epilepsy are significantly better in those patients with more than 50% of focal or regional ictal onsets than those with 25% or less focal or regional onsets.[56] Two few of our frontal lobe patients have had sufficient post-operative followup to determine if the same relationship holds in this group. Nevertheless, it is important to consider ictal variability when formulating one's hypothesis about the epileptogenic zone.

As mentioned, 76% of temporal lobe seizures show an evolution in the ictal pattern within 10 sec of onset. Frontal lobe complex partial seizures have been described as very brief compared to temporal lobe seizures[11,15] although one of the earliest publications on this entity noted seizures lasting 2 to 5 min.[4] On the basis of depth recordings in temporal lobe seizures it has been suggested that rapid propagation of ictal discharges from the initial focus is associated with poor outcomes after temporal lobectomy.[57] There was no differences in the mean ± S.D. of the time of pattern evolution in the three groups which we studied. Comparing the distributions of the times required for an initial pattern to evolve in these three groups (temporal, frontal and the T/F-F/T group; Figure 6), there is still little difference in the groups. However, we note that the temporal group has a long tail due to seizures which never change their pattern (i.e. — begin and remain focal or regional). This could explain why the seizures of temporal lobe origin are felt to be longer, although statistical analysis of that impression has not been performed.

Discussion

Although the surface EEG (interictal) has been used for over 30 years to define an epileptogenic focus, some authors have doubted its applicability.[2,33-37] Dodrill, et al.[58] found several surface interictal EEG variables were independently related to outcomes following surgical resection. Lieb, et al.[57] also noted non-redundant information from interictal and ictal EEG records

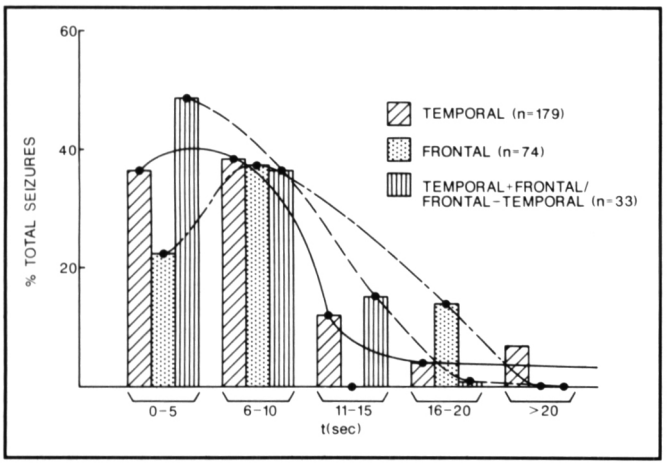

Figure 6 — The time it took for a change in ictal pattern to occur after seizure onset is plotted against the total percentage of seizures as a histogram in bins of 5 seconds. While the combined TF/FT group appeared to change the fastest, few from any group changed after 10 seconds. The temporal lobe group has a few seizures which never change from the pattern at onset.

with respect to outcomes. In preliminary studies we also reported a relationship between surface ictal EEG patterns and outcome[56,59] but did not look at interictal records.

The present study attempted to broaden our observations by comparing interictal and ictal records from frontal and temporal lobe epilepsy. We found 33% of frontal interictal EEG's to be focal, a figure intermediate with those in the literature and lower with those of our temporal epilepsy group. However, this figure was higher than the number of focal ictal onsets in the frontal seizure group. There was also a greater number of focal interictal than ictal EEG's in the temporal lobe seizure group. The lower number of focal ictal onsets is likely due to the fact that we did not combine diffuse low voltage fast or attenuated onsets which later became focal with the focal group as in studies from other centers. The ratio of focal EEGs on interictal to ictal records was approximately 3:1 for the frontal group and 2:1 for the temporal group. This difference in ratios is probably explained by the fact that in temporal lobe epilepsy the seizures begin or propagate rapidly to medial limbic structures, the hippocampus and amygdala, which are in good proximity to sphenoidal recording electrodes.[60] Frontal lobe seizures can also propagate through medial limbic structures i.e. — from the superior dorsolateral frontal cortex to the cingulum via the supplementary motor area and from inferior premotor regions to posterior orbital frontal lobes.[61] The latter structures are simply not as accessible to surface or special recording techniques such as the sphenoid. Thus, the ictal recordings may reveal a non-focal EEG onset after it has moved from its site of origin, and this may be more true with frontal than with temporal lobe seizures. The focal interictal spike had a similar accuracy rate in both the frontal and temporal lobe epilepsy groups (Table 3B).

It is our impression that the study has not yet been done which definitively determines the true efficacy of surface EEG recordings. Such a study would require a specific hypothesis, i.e., extracranial EEG can accurately determine a focal epileptogenic zone. The focus as defined would have to be verified by results of intracranial recordings and surgery. The specificity of the intracranial recordings would have to be known exactly to determine the Type II error (beta statistic), in a relatively large population, and long follow-up periods would be required. This could be undertaken by one of several epilepsy surgery groups in the world and probably should be. Pending that, since many operations have been successfully performed on the basis of surface EEG alone, and because in our temporal lobe series we found no significant differences in outcomes in those who did not have Phase II recordings,[56,59] we like others, feel comfortable continuing the use of this fundamental, noninvasive, diagnostic tool.

What of the differences in frontal and temporal lobe EEG ictal patterns? We noted that bilateral slowing or diffuse (i.e., general low voltage fast) patterns were equally common at onset in temporal and frontal lobe seizures. The proportion of regional plus focal onsets was also equal in the two groups. The main difference lay in the regional onset group which was twice as common in frontal as in temporal lobe seizures. This may be due to the "lobar" definition of regional in those studies which necessarily includes a greater area in the frontal lobe. Another contributing factor was that fewer of the diffuse onset ictal EEG's later became focal in frontal lobe epilepsy. Because a regional frontal onset implicates the entire frontal lobe, if

surgery is considered intracranial recordings must be made. It is hoped that in the future improved brain imaging combined with EEG brain mapping or frontal activation paradigms paired with cognitive evoked potentials[62,63] may provide improved noninvasive information.

There is a slightly greater variability in seizure onsets within a single patient in the temporal lobe group than in the frontal lobe group, which has not previously been evaluated. The ictal patterns appeared to evolve with similar time courses in the frontal, TF/FT, and temporal groups with 81%, 77%, and 76% changing from an initial to secondary pattern within 10 sec, although one subdivision of the temporal lobe population never shows a pattern change. This similarity is curious since it has been suggested that frontal lobe seizures propagate faster than temporal lobe seizures.[11,16,45,51] Speed of propagation cannot be determined from surface EEG recordings, therefore the interpretation of our data on ictal pattern development must be guarded, but bear further exploration. Practically, we believe that the term "onset" should only be applied to a pattern seen from the beginning of the electrographic seizure to no more than 10 sec after onset, since most seizures change within this time period and since postsurgical outcomes in patients with initial focal records and initial attenuated records are not identical when stringent outcome criteria are used in temporal lobe epilepsy.[56,59]

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