Multiple Electrodes for Detecting Spikes in Partial Complex Seizures

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ABSTRACT: The contribution of various electroencephalographic electrodes in detecting spikes from patients with seizures of suspected anterior temporal origin was prospectively studied with a standard protocol. The following electrodes were studied: International Standard 10-20 positions F7-8 and A1-2, sphenoidal (SP), nasopharyngeal (NP), anterior temporal (T1-2), mandibular notch surface (MNS), and mandibular notch subdermal (MNSD). Twenty patients were recorded of whom 16 demonstrated anterior temporal spikes. There was no difference in the number of spikes detected by SP, MNS, MNSD, or T1-2 electrodes ($p < 0.05$); however these electrodes detected significantly more spikes than NP, F7-8, or A1-2. The SP electrode recorded spikes of highest amplitude ($p < 0.05$). We conclude that for patients suspected of having seizures of anterior temporal origin, (1) a substantial number of spikes will be missed if only the International Standard electrode system is employed; (2) in comparison to SP electrodes the non-invasive and easily applied MNS or T1-2 electrodes will detect almost all spikes and should be used in outpatient EEG recordings; (3) NP electrodes provide no information that cannot be obtained by more reliable and better tolerated electrodes.

RÉSUMÉ: Utilisation d'électrodes multiples pour détecter les pointes dans l'épilepsie partielle complexe Nous avons étudié de façon prospective, en utilisant un protocole standard, la contibution de différentes électrodes électro-encéphalographiques pour la détection des pointes chez des patients présentant des crises épileptiques qu'on soupçonnait être d'origine temporale antérieure. Les électrodes suivantes ont été étudiées: International Standard 10-20 en position F7-8 et A1-2, sphénoïdale (SP), nasopharyngienne (NP), temporale antérieure (T1-2), de surface à l'échancrure sigmoïde de la mandibule (MNS) et sous-dermique à l'échancrure sigmoïde de la mandibule (MNSD). Nous avons fait l'enregistrement chez 20 patients, dont 16 présentaient des pointes temporales antérieures. Il n'y avait pas de différence dans le nombre de pointes détectées par les électrodes SP, MNS, MNSD ou T1-2 ($p<0.05$); cependant, ces électrodes détectaient significativement plus de pointes que les électrodes NP, F7-8 ou A1-2. L'électrode SP enregistrait des pointes de plus grande amplitude ($p<0.05$). Nous concluons que, pour les patients chez qui on soupçonne des crises épileptiques originant de la région temporale antérieure, (1) un nombre substantiel de pointes sera manqué si l'on n'utilise que le système d'électrodes International Standard; (2) par comparaison avec les électrodes SP, les électrodes MNS ou T1-2, qui sont non-invasives et d'application facile, détecteront presque toutes les pointes et devraient être utilisées pour les enregistrements électro-encéphalographiques chez tous les patients externes; (3) les électrodes NP ne fournissent pas d'information qui ne soit obenue au moyen d'électrodes plus fiables et mieux tolérées.

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In patients with partial complex seizures the detection of electroencephalographic interictal spikes assists with both diagnosis and site of ictal onset. For those patients with anterior (including mesial) temporal originating seizures the classic interictal spike is recorded from the F7-8 and ear (A1-2) electrodes[1] when the International Standard 10-20 electrode system[2] is used. Additional "non-standard" electrodes have been used to augment the detection of spikes from anterior temporal lobe structures (for review see reference 3). However, there are few published studies that have attempted a simultaneous comparative assessment of these "non-standard" electrodes.

In this report we describe a comparative study of several electrodes used simultaneously in an attempt to define which of these is the best for detecting interictal spikes of anterior temporal lobe origin.

Methods

Subjects

Patients from one author's (RMS) outpatient epilepsy clinic were selected who fulfilled these criteria: (1) a clinical diagnosis of partial complex seizures, (2) prior standard electroencephalograms (EEGs) demonstrating spikes predominantly from F7-8, A1-2, or equipotential at F7-T3/F8-T4 and (3) agreement to participate in the study after informed consent was obtained.

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All patients were sleep deprived the night prior to the study recording session. To ensure sleep, secobarbital 100 mg was orally administered upon arrival in the EEG laboratory. There were no adjustments of anti-epileptic medications.

Patient data was obtained from the clinic charts.

EEG Recording Parameters

Silver-silver chloride surface cup electrodes were applied to the following International 10-20 positions:[2] F3-4, F7-8, T3-4, A1-2, CZ and PZ. Identical electrodes were applied bilaterally to the "anterior temporal" (T1-2) positions (one-third of the distance from the external auditory meatus to the external canthus of the eye and up one centimeter)[4] and over the mandibular notch surface (MNS) located 2.5 cm anterior to the tragus of the ear and immediately inferior to the zygoma. Platinum alloy subdermal needle EEG electrodes[5] (mandibular notch subdermal or MNSD) were inserted immediately adjacent to the MNS electrodes. Sphenoidal (SP) electrodes (silver-silver chloride wire insulated but bared at the tip) were inserted adjacent to MNS and MNSD electrodes using standard techniques.[6] Nasopharyngeal (NP) silver-silver chloride ball electrodes were used in all but two patients (who could not tolerate insertion).

All electrodes were referred to PZ except A1 and A2 which were linked (A1-A2) and used as a monitor of electrocardiogram artefact; T3-4 were linked to CZ to identify sleep potentials.

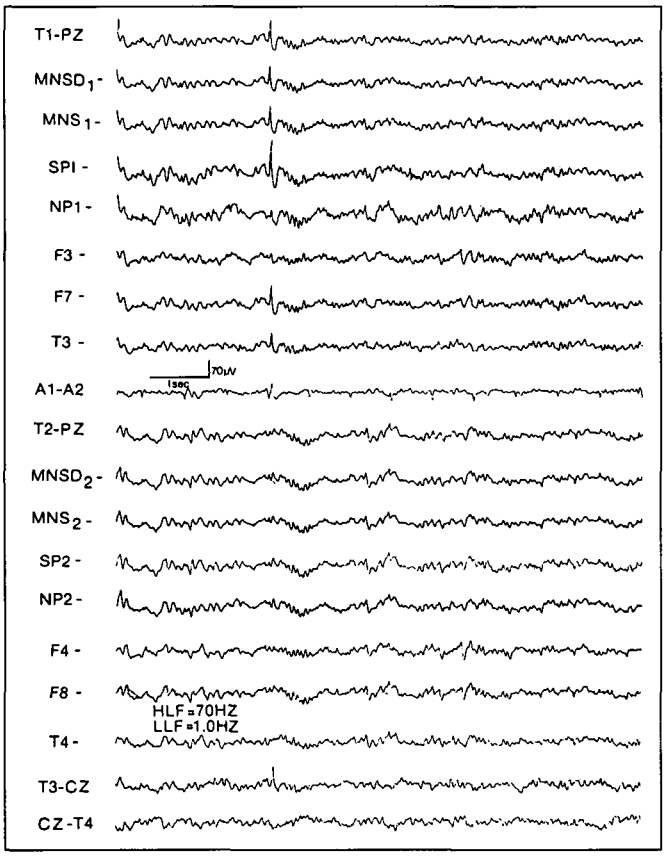

Figure 1 — Left temporal spike in one study montage: spike detection by all left side non-standard electrodes, A1, F7 and T3; maximum amplitude at SP1. See text for abbreviations; all electrodes referred to PZ unless otherwise indicated.

All recordings were performed with a Grass Model 8 19-Channel electroencephalograph.

EEG Data Collection

The EEG technologist constructed four montages using the channel derivations described above; all montages contained the same channel derivations but in a different order. The electroencephalographer was blind to the channel derivation sequences in each montage until the study was terminated.

The technologist selected one montage per patient and one montage was used throughout one recording session; each patient had a single recording.

EEGs were visually inspected and spikes identified using Gloor's criteria[7] as closely as possible. Whenever a spike was observed in any channel, waveforms occurring simultaneously in other channels were inspected for spike characteristics. Only those channels with spike morphology were counted as "detections"; other simultaneous waveforms (e.g. sharply contoured theta waves) were counted as "non-detections". Each spike's amplitude was determined by measuring (with calipers) the vertical distance between the peak pen deflection and the lowest trough on either the ascending or descending phase of the spike.

After all spikes were assessed channel derivation codes were broken. Spikes expressing maximal amplitude at F3-4 and T3-4 were excluded. Spikes in the A1-A2 channel were not measured for amplitude but were counted in the detection data. Small sharp spikes (benign epileptiform transients of sleep) were excluded.[8]

Spikes from each electrode were analyzed according to detection, amplitude (except A1, A2), and concordance of detection with other electrodes. Statistical testing was performed using the Tukey honestly significant difference (hsd) procedure for multiple comparisons,[9] at 95% confidence limits.

Figure 1 illustrates one study montage and a typical spike detected by multiple electrodes.

Results

Patients

Twenty patients were studied; four had no spikes and were excluded from further analysis. The mean age was 32.1 years (range 17-60). All had normal neurological examinations, normal intelligence (with the exception of 1 patient with mild mental subnormality), and normal contrast enhanced computed tomographic brain scans.

The mean recording time was 88 minutes (range 85-95) with awake and sleep recordings obtained in all patients.

Spike Detections

One hundred and ninety-two spike "events" were identified with a mean (± standard deviation) of 12±8.5 per patient.

Spike detections by each electrode are shown in Table 1. There was no statistically significant difference in the number of detections amongst the SP, MNS, MNSD and T1-2 electrodes. However, each of these electrodes detected more spikes ($p < 0.05$) than the F7-8, NP, or A1-2 electrodes (allowing for the two patients who did not have NP electrodes inserted). There was no difference in detections amongst F7-8, A1-2 and NP electrodes.

There were four patients (with 16, 11, 1 and 1 spike "events", respectively) who would not have had any detections

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Table 1: Spike Detections and Amplitudes by Electrode

Electrode	Detections (Total = 192) Quantity	% of Total	Mean Amplitude (Microvolts)	Standard Deviation of Amplitude
SP	187	97.3[a]	140[a]	42
MNS	178	92.7[a]	105[b]	30
MNSD	178	92.7[a]	105[b]	31
T1-2	166	86.4[a]	107[b]	34
F7-8	111	57.8[b]	119[b]	38
A1-2[c]	107	55.7[b]	—	—
NP[d]	100	62.9[b]	110[b]	33

[a,b] Values in column with the same superscript not significantly different ($p < 0.05$)
[c] Spike amplitude of A1, A2 spikes not measured
[d] Two patients with a total of 33 spikes did not have NP electrodes; percentage calculated from a total of 159 spikes in those patients with NP electrodes

if only F7-8 and A1-2 were used and all patients would have had spikes detected if any one of the non-standard electrodes had been used.

Spike Amplitudes

The mean (± standard deviation) of spike amplitude at each electrode position is shown in Table 1. There was no statistically significant difference in mean amplitude at any of the sites except for the SP electrode which demonstrated spikes of a higher mean amplitude than any other electrode ($p < 0.05$).

Concordance of Detection

Table 1 describes the number of detections by each electrode but seventeen different combinations of detections were observed amongst the electrodes. For example, one spike event might be detected only by SP and the mandibular notch electrodes but on other occasions more widespread involvement could occur (Figure 1).

Virtually all (92-97%) NP spikes were simultaneously detected by the other non-standard electrodes but only 61-69% of SP, MNS, MNSD, or T1-2 spikes were concordant with NP spikes.

The non-standard electrodes (except NP) simultaneously detected 97-98% of F7-8 or A1-2 spikes whereas the converse was true in 58-65% of instances.

Discussion

When the International Standard 10-20 Electrode System[2] is used the interictal spikes in patients with anterior temporal lobe originating seizures are typically recorded from the F7-8 and A1-2 electrodes.[1] However, F7-8 is in closer proximity to the inferior frontal lobe than the temporal lobe[10] and therefore may not be optimally positioned for detecting anterior temporal discharges. A number of non-standard electrodes have been described to augment anterior temporal detections;[3] sphenoidal,[11] nasopharyngeal,[12-14] "anterior temporal" (T1-2),[4] and more recently "mini-sphenoidal",[5] and zygoma[15] electrodes.

Despite abundant documentation over many years of the non-standard electrodes' abilities to *detect* spikes[3] there have been few attempts to critically evaluate the performance of any one of these electrodes against others. Eleven studies in the literature have simultaneously evaluated at least two of the non-standard electrodes; four of these are presented in abstract form[17-20] and a critical appraisal is not possible; the seven complete publications[5,15,16,21-24] are summarized in Table 2.

Our study is the first to assess simultaneously SP, NP, MNS, MNSD and T1-2 electrodes with a standard protocol. Despite methodological differences, our findings generally agree with the conclusions of previous studies (Table 2).

In the present study the SP spikes had a significantly greater mean amplitude than the spikes detected by all other electrodes. Although the SP electrodes detected more spikes than either of the MNS, MNSD, or T1-2 electrodes, this difference was not statistically significant. The performance of the MNS, MNSD and T1-2 electrodes as measured by both amplitude and detection was statistically indistinguishable and each of these electrodes detected more spikes than NP, F7-8, or A1-2 electrodes.

The concordance data suggests that the neural generators for spikes detected by SP, MNS, MNSD and T1-2 electrodes are similar; therefore only one of these electrodes need be used in the individual patient if one wishes to determine only the presence of anterior temporal originating spikes. However, by using multiple electrodes a more comprehensive evaluation of the electrical field can be obtained.[22,23] Using any of SP, MNS,

Table 2: Comparative Studies Using a Minimum of Two Non-Standard Electrodes in Patients with Partial Complex Seizures

Authors	Electrodes studied[a]	Major Conclusions
Sindrup et al[15]	SP, ZY[b]	– ZY plus standard electrodes identified 79% of patients with SP spikes
Binnie et al[16]	NP, "anterior temporal" (15 mm anterior to T1-2)	– "Anterior temporal" electrodes detected all foci detected by NP
Laxer[5]	"mini-sphenoidal",[c] SP	– "Mini-sphenoidal" spikes 30% lower amplitude than SP spikes
Sperling et al[21]	NP, T1-2	– T1-2 invariably detected spikes detected by NP – NP uncomfortable, prone to artefact
Sperling et al[22]	NP, SP	– SP superior to NP for spike detection and amplitude – NP uncomfortable, prone to artefact
Morris et al[23]	Multiple closely spaced scalp and NP	– Electrode approximately equivalent to T1-2 demonstrated maximum voltage most often
Homan et al[24]	SP, T1-2	– SP and T1-2 detected more spikes than standard electrodes – SP did not detect significantly more spikes than T1-2

[a] In addition to standard scalp electrodes
[b] Probably equivalent to MNS electrodes in present study
[c] Equivalent to MNSD electrodes in present study

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MNSD, or T1-2 electrodes will substantially increase the likelihood of detecting anterior temporal spikes beyond that which can be achieved with the International Standard 10-20 system[2] alone since the F7-8 and A1-2 electrodes detected only 58% and 56%, respectively, of all spikes.

The advantages of MNS and T1-2 electrodes compared to SP electrodes for out-patient EEG recording are the lack of patient discomfort and a physician is not required for placement.

The NP electrodes detected significantly fewer spikes than SP, MNS, MNSD, or T1-2 electrodes. Further, when a NP spike was seen it was nearly always detected by one of the other non-standard electrodes. Therefore we have found, as have other authors,[21,22] that NP electrodes provide no information that cannot be obtained with more reliable and comfortable electrodes.

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