5-17-2016

Spike voltage topography in temporal lobe epilepsy

Ali Akbar Asadi-Pooya
Thomas Jefferson University, Aliakbar.Asadi-Pooya@jefferson.edu

Marjan Asadollahi
Thomas Jefferson University, marjan.asadollahi@jefferson.edu

Shoichi Shimamoto
Thomas Jefferson University, shoichi.shimamoto@jefferson.edu

Matthew Lorenzo
Thomas Jefferson University, matthew.lorenzo@jefferson.edu

Michael R. Sperling
Thomas Jefferson University, Michael.Sperling@jefferson.edu

Spike voltage topography in temporal lobe epilepsy

Authors: Ali A. Asadi-Pooya, M.D., Marjan Asadollahi, M.D., Shoichi Shimamoto, M.D., Matthew Lorenzo, Michael R. Sperling, M.D.

Jefferson Comprehensive Epilepsy Center, Department of Neurology, Thomas Jefferson University, Philadelphia, Pennsylvania, USA.

Address for correspondence:

Ali A. Asadi-Pooya, M.D.

Department of Neurology

901 Walnut Street, Suite 435

Philadelphia, PA 19107

Phone: 215-955-1222

Fax: 215-955-3745

E-mails: aliasadipooya@yahoo.com; marjan.asadollahi@jefferson.edu; shoichi.shimamoto@jefferson.edu; matthew.lorenzo@jefferson.edu; michael.sperling@jefferson.edu

Running title: Spike voltage topography.

Key words: EEG; Map; Spike; Temporal lobe epilepsy; Voltage topography.

Word count for the paper: 1655. Word count for the abstract: 237.

Number of text pages: 6; Number of references: 9; Number of figures: 3; Number of tables: 2.

Abstract

We investigated the voltage topography of interictal spikes in patients with temporal lobe epilepsy (TLE) to see whether topography was related to etiology for TLE. Adults with TLE, who had epilepsy surgery for drug-resistant seizures from 2011 until 2014 at Jefferson Comprehensive Epilepsy Center were selected. Two groups of patients were studied: patients with mesial temporal sclerosis (MTS) on MRI and those with other MRI findings. The voltage topography maps of the interictal spikes at the peak were created using BESA software. We classified the interictal spikes as polar, basal, lateral, or others. Thirty-four patients were studied, from which the characteristics of 340 spikes were investigated. The most common type of spike orientation was others (186 spikes; 54.7%), followed by lateral (146; 42.9%), polar (5; 1.5%), and basal (3; 0.9%). Characteristics of the voltage topography maps of the spikes between the two groups of patients were somewhat different. Five spikes in patients with MTS had polar orientation, but none of the spikes in patients with other MRI findings had polar orientation (odds ratio = 6.98, 95% confidence interval = 0.38 to 127.38; p = 0.07). Scalp topographic mapping of interictal spikes has the potential to offer different information than visual inspection alone. The present results do not allow an immediate clinical application of our findings; however, detecting a polar spike in a patient with TLE may increase the possibility of mesial temporal sclerosis as the underlying etiology.

Introduction

Since its inception, scalp electroencephalography (EEG) has been interpreted by visual inspection of waveforms using the assumption that activity at a given electrode is a representation of the activity of the cortex beneath it [1]. In many patients, this method of interpretation is sufficient to localize an interictal activity to one hemisphere or even one lobe, but such method has limitations and may lead to misinterpretation. Scalp EEG contains more information and the advent of digital EEG has allowed more advanced analysis of the EEG data. For example, spike voltage topography or 3-D voltage maps of cortical activity, is a descriptive way of defining dipole localization and orientation [1]. Interictal spikes are usually cortex negative, meaning the dipolar currents are flowing into the cortex. Therefore, a focal brain activity typically produces a dipolar field with two poles, a negative and a positive [2]. Often, the negative pole of a dipolar map is not exactly above the region of origin and may in fact be remote. Previous studies have suggested voltage mapping of interictal spikes as a way to improve non-invasive EEG localization of focal epilepsies [1, 2]. This data can complement other localizing data (e.g., EEG visual inspection and seizure semiology). However, these studies noted that spike potentials could vary considerably [1] and the diagnostic value of this technique is remained to be elucidated.

The scope of this study is to describe 3-D voltage maps of interictal epileptiform activities in patients with temporal lobe epilepsy (TLE) to identify the prevalence of different patterns of spike voltage topography in these patients. We also investigated whether topography was related to etiology for TLE. This may shed light on the significance and clinical applicability of this technique to improve non-invasive EEG localization of temporal lobe epilepsies.

Methods

Patients

Adult patients with TLE, who had epilepsy surgery for drug-resistant seizures between January 2011 and January 2014 at Jefferson Comprehensive Epilepsy Center, were studied. Two groups of patients were studied, according to their magnetic resonance imaging (MRI) results: patients with mesial temporal sclerosis (MTS) and patients with other MRI findings. Patients with dual pathology, insufficient number of interictal spikes, or with psychogenic nonepileptic seizures were excluded from this study.

Measures

The long-term EEG recordings from preoperative evaluation were studied. In each patient, we identified ten interictal spikes in stages 1-3 of sleep. The first ten spikes in two different nights and on artifact free backgrounds were selected. If the patient had frequent spikes we selected a handful in each night. The topographic voltage maps of the designated spikes at the peak were created using BESA 3-D mapping software [2]. We classified the temporal spikes as **1) Polar,** if there was an oblique map with a negative pole on the cheek or around the eye and a positive pole in posterior head regions (Figure 1); **2) Basal,** if activation presented itself with a near- vertical 3-D map with a strong negative pole at the ear or below and the positive pole near central electrodes (Figure 2); **3) Lateral,** if there was a strong negative pole at or around the fronto-temporal (F7 or F8) or mid-temporal [T3 (T7) or T4 (T8)] electrodes and a positive pole at the opposite hemisphere (Figure 3); and finally, **4) Others,** in all other circumstances.

Statistical analysis

Demographic variables and relevant clinical variables were summarized descriptively to characterize the study population. Chi square test and t-test were used for statistical analyses.

Odds ratio and 95% confidence interval were calculated. P value less than 0.05 was considered as significant.

Ethical approval

This study was conducted with approval by Thomas Jefferson University Institutional Review Board. No informed consent was required, as it was a retrospective study.

Results

Thirty-four patients were studied. Twenty-one patients had mesial temporal sclerosis, five had a normal MRI, and 8 patients had abnormal non-MTS MRI findings (3 patients had encephalomalacia/gliosis; 2 patients had tumors; 1 patient had cortical dysplasia; 1 had a cavernoma; and 1 patient had an encephalocele). Demographic and clinical characteristic of the patients are shown in Table 1. Characteristics and orientation of 340 interictal spikes were investigated. The most common type of spike orientation was others (186 spikes; 54.7%), followed by lateral (146; 42.9%), polar (5; 1.5%), and finally, basal (3; 0.9%). All patients had at least one spike with other polarity. Thirty-two patients (20 patients with MTS and 12 with other MRI findings) had at least one spike with lateral polarity. Three patients with MTS (14.3%) and one patient with other MRI finding (7.7%) had more than two spike populations with respect to polarity ($p = 0.4$). Characteristics of the voltage topography maps of the interictal spikes are shown in Table 2. Characteristics of the voltage topography maps of the interictal spikes between the two groups of patients were marginally significantly different. Five spikes in patients with MTS (in 3 patients) had polar orientation, but none of the spikes in patients with other MRI findings had polar orientation (odds ratio = 6.98, 95% confidence interval = 0.38 to 127.38; $p = 0.07$). Other spike polarities were not differently observed between the groups. The p value for the comparison of the number of the patients with polar spikes (three in the MTS group and none in the other group) was 0.1.

Discussion

In the present study, we observed that spikes with different orientations may be seen in patients with TLE and even orientation of the spikes in one patient may vary from one interictal spike to another. We also observed that characteristics of the voltage topography maps of the interictal spikes between patients with MTS-TLE were marginally significantly different from that in other TLE patients. Clinical investigations of epileptiform discharges using voltage topography have been ongoing since the early 1990s. Voltage mapping of interictal spikes has been suggested as a way to improve non-invasive EEG localization of focal epilepsies [1, 2]. However, previous studies noted that spike potentials could vary even within one lobe [1]. We had a similar observation. We observed that among a uniform group of patients with TLE (i.e., those with MTS) interictal spike potentials may vary in polarity, even in one single patient. In contrast to previous assumptions that initial spike currents into the basal or polar surfaces of the temporal lobe are common in mesial temporal lobe epilepsy [2], we observed that only 2.4% of the spike population in patients with mesial temporal sclerosis and TLE were polar or basal. However, detecting a polar spike in a patient with TLE may increase the possibility of MTS as the underlying etiology. In brief, spikes with polar orientation in patients with TLE are rare, but may improve non-invasive EEG diagnosis of TLEs. Previous studies of spike voltage topography have shown mixed results. In one previous study [3], the authors investigated 15 patients; 10 patients suffered from partial epilepsy of presumed mesiotemporal origin and the other five presented partial epilepsy with non mesiotemporal or extra temporal epileptic foci. In all cases, visual inspection of EEG traces demonstrated temporal interictal spikes. The authors studied the spike voltage distributions and found that spike voltage topography revealed no significant differences between the two groups [3]. However, in another study of the EEGs of 45 patients with focal epilepsy different results were observed [4]. Analysis of spike voltage topography revealed two distinct patterns - dipolar, type 1 (negative fields that were sharply defined, had steep voltage gradients, were located inferiorly, and were associated with distinct, contralateral positive fields), and non-dipolar, type 2 (broad negative fields that extended to or beyond the midline, gradual voltage gradients, and less clear or no associated positive fields). Correlations with clinical data and intracranial EEG suggested that type 1 spikes originated in mesial temporal structures, while type 2 spikes arose from temporal or frontal neocortex [4]. Similar findings have been reproduced in other studies [5, 6]. Those authors concluded that spike voltage topography and equivalent dipole localization were useful in the presurgical evaluation of patients with focal epilepsy [4].

In conclusion, scalp EEG has the potential to offer more spatial and temporal information than visual inspection alone. For example, detecting a polar spike in a patient with TLE may increase the possibility of mesial temporal sclerosis as the underlying etiology. Besides, with the help of modern computer-assisted analysis, this information is more accessible. Spatio-temporal analysis of scalp voltage fields may allow for improved localization of likely cerebral origins of electroencephalographic waveforms. The use of modern techniques- such as equivalent dipole source modeling, 3-D MRI reconstructions, and realistic head models- may improve accuracy of dipole localization [1, 7-9]. These techniques are more sophisticated and require more in-depth training and experience for proper application and interpretation. The present results do not allow an immediate clinical application of our findings and more work is needed to investigate and improve the applicability of such techniques and also to clarify their role and value in clinical practice. Our study had some limitations. This was a small retrospective study and there was a potential for selection bias. The number of patients may have affected the results. Because of the small number of patients (e.g., 3 patients had polar and 3 others had basal spikes) we could not study any possible correlation between outcome after surgery and preoperative 3-D voltage maps of interictal epileptiform activities in patients with TLE. For diagnostic purposes, we tried to overcome to this limitation by studying 10 spikes per each patient, but still lack of statistically significant differences may be the consequence of this limitation.

Acknowledgment

This was a non-funded study.

Conflict of interest

Ali A. Asadi-Pooya, Marjan Asadollahi, Shoichi Shimamoto, and Matthew Lorenzo have no conflict of interest to disclose. Michael R. Sperling, M.D., Research: contracts with Thomas Jefferson University with Dr,. Sperling as PI with: Eisai, UCB Pharma, Sunovion, SK Life Sciences, Marinus, Lundbeck, Medtronics, Accorda, Upsher-Smith, Brain Sentinel, Pfizer, Glaxo; research support from DARPA and NIH through Thomas Jefferson University.

All authors have approved the final article.

References

1. Rose S, Ebersole JS. Advances in spike localization with EEG dipole modeling. Clin EEG Neurosci 2009; 40: 281-287.
2. http://www.besa.de/wp-content/uploads/2014/06/BESA-Quick-Guide-on-3D-Maps.pdf
3. Do Marcolino C, Baulac M, Samson-Dollfus D. Topographic analysis of interictal spikes in the presurgical evaluation of severe partial epilepsy. Neurophysiol Clin 1994; 24: 20-34. [Article in French; abstract was available].
4. Ebersole JS, Wade PB. Spike voltage topography and equivalent dipole localization in complex partial epilepsy. Brain Topogr 1990; 3: 21-34.
5. Ebersole JS, Wade PB. Spike voltage topography identifies two types of frontotemporal epileptic foci. Neurology 1991 Sep; 41: 1425-1433.
6. Boon P, D'Havé M. Interictal and ictal dipole modelling in patients with refractory partial epilepsy. Acta Neurol Scand 1995; 92: 7-18.
7. Boon P, D’Have M, Adam C, Vonck K, Baulac M, Vandekerckhove T, et al. Dipole modeling in epilepsy surgery candidates. Epilepsia 1996; 38: 208-218.
8. Cuffin BN. EEG localization accuracy improvements using realistically shaped head models. IEEE Trans Biomed Eng 1996; 43: 299-303.
9. Roth BJ, Ko D, von Albertini-Carletti IR, Scaffidi D, Sato S. Dipole localization in patients with epilepsy using the realistically shaped head model. Electroencephalogr Clin Neurophysiol 1997; 102: 159-166.

Figure 1. A topographic map of a right anterior temporal sharp wave with polar orientation.

Figure 1 legend. A polar map with a negative pole around the right cheek and a positive pole in posterior head regions.

Figure 2. A topographic map of a right anterior temporal sharp wave with basal orientation.

Figure 2 legend. Activation presented itself with a near-to-vertical topographic map with a strong negative pole below the ear and the positive pole near the vertex.

Figure 3. A topographic map of a left mid-temporal spike with lateral orientation.

Figure 3 legend. The topographic map shows a left mid-temporal spike originating at the lateral cortical convexity near the T3 (T7) electrode. The corresponding positive pole is on the other side of the head.