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Simulation von tangentialer und radialer elektrischer Gehirnaktivität: unterschiedliche Empfindlichkeit in EEG und MEG.
Simulation of tangential and radial electric brain activity: different sensitivity in EEG and MEG.

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Kurzfassung

Basierend auf der Hauptrichtung der neuronaler Ströme bezüglich der lokalen Schädelform ist es üblich zwischen tangentialer und radialer Aktivität zu unterscheiden. Tangentiale Aktivität hat ihren Ursprung hauptsächlich in den Wänden der Sulci, während radiale Aktivität hauptsächlich in den Böden der Sulci und den Gyri zu finden ist. Es ist etabliert, dass MEG sensitive für tangentiale Aktivität und EEG für tangentiale und radiale Aktivität ist. Daher ist es erstaunlich, dass Studien an epileptischen Patienten Fälle berichten in denen Spikes im MEG aber nicht im EEG gefunden werden. Eine niedrige Sensitivität des MEGs bezüglich der Hintergrundaktivität wurde als möglicher Grund für diesen Befund diskutiert. Daher wird in dieser Studie das Signal-zu-Rausch Verhältnis (SNR) von simulierten Spikes mit verschiedenen Orientierungen unter Berücksichtigung verschiedener Hintergrundaktivität in realistischen Kopfmodellen analysiert. Für eine feste, realistische Hintergrundaktivität zeigt sich ein höheres SNR im MEG solange die Orientierung des Spikes nicht mehr als 30 Grad von der tangentialen Richtung abweicht. Im EEG ist das SNR der Spikes dagegen höher solange die Orientierung der Aktivität nicht mehr als 45 Grad von der radialen Richtung abweicht. Die gezeigten Ergebnisse können zur Erklärung der experimentell gefundenen Unterschiede in EEG und MEG Signalen beitragen.

Abstract

Based on the main direction of the neuronal currents with respect to the local skull curvature, it is common to distinguish between tangential brain activity originating mainly from the walls of the sulci and radial brain activity originating mainly from the gyri or the bottom of the sulci. It is well known that MEG is more sensitive to tangential activity while EEG is sensitive to both radial and tangential activity. Thus, it is surprising that studies in epileptic patients report cases were spikes are visible in MEG but not in EEG. Recently, it was discussed that a lower sensitivity of MEG to background activity might be the reason for the spike visibility in MEG but not in EEG. Consequently, we analyze the signal-to-noise ratio (SNR) of simulated spikes at varying orientations and with varying background activity in realistic head models. For a fixed realistic background activity, we find a higher SNR for spikes in the MEG as long as the spike orientation is not more than 30 degrees deviating from the tangential direction. Vice versa the SNR for spikes in the EEG is higher as long as the spike orientation is not more than 45 degrees deviating from the radial direction. Our simulations provide a possible explanation for the experimentally observed differences in EEG and MEG signals.

1 Introduction

Electroencephalography (EEG) and Magnetoencephalography (MEG) are used in the diagnosis of epileptic patients. Both techniques are non-invasive and have a high time resolution, which is the basis for the detection and eventually the localization of ictal and interictal spike activity in the brain. In general, EEG and MEG signals are generated by the same underlying bioelectric sources. However, there are a few theoretical and practical differences in the sensitivity of both techniques (e.g. [1], [2]). The perhaps most important difference with respect to the recording of epileptic spikes is that EEG is about 6-12 times more sensitive to radially oriented sources than MEG [3], [4], [5]. Thus, it is to some extent surprising that studies in epileptic patients report cases were spikes are visible in MEG but not in EEG (for review see e.g. [6]). Similarly, in sensory processing sometimes MEG signal components occur where there are no EEG components. It was suggested that exclusive MEG spike detection is likely influenced by overlapping background activity (especially radial background activity) in EEG.
Thus, the aim of our study was to investigate the influence of radial and tangential background activity on radial and tangential epileptic spike activity.

2 Methods

We used T1-weigthed MRI datasets (160 sagittal slices with 1mm resolution) of 4 healthy volunteers (2 males, 2 females, all right-handed). Out of these data sets, cortical surfaces were segmented and triangulated with a triangle side length of 3 mm in order to serve as source spaces. For the four volunteers, this resulted in 18,259, 14,871, 17,035, and 14,288 nodes; where at each node a dipolar source was positioned. The orientation of the electric current dipole at each node was set equivalent to the surface normal vector at this node. We chose 6 cortical regions for each volunteer and each hemisphere as indicated in Fig. 1: frontal, fronto-temporal, temporo-parietal, central, parietal, and occipital, resulting in 48 regions total. In each region, a trace of 6 neighbor nodes (6 dipolar sources, respectively) was algorithmically selected based on the orientations of the surface normal vectors at each node point. The trace of 6 dipolar sources always included one source with a mainly radial orientation on the crown of the gyrus and one source with a mainly tangential orientation in the wall of the sulcus. The inset in Fig. 1 illustrates an example of such a dipolar source trace. The trace represents the transition from radial to tangential direction along the cortical surface in terms of a set of node points. A synthetic spike time curve served as source wave form.

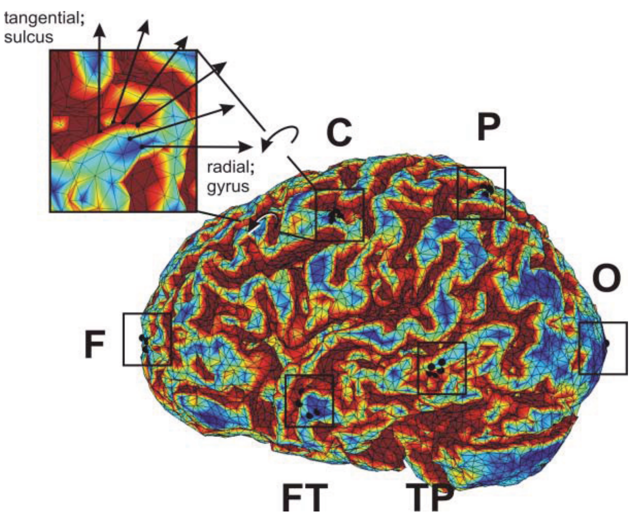

Figure 1 Triangulated cortical surface of one volunteer (color code: radial – blue; tangential – red). The six regions in this hemisphere are marked by squares (F – frontal, C – central, P – parietal, O – occipital, FT – fronto-temporal, and TP – temporo-parietal). The rotated close-up (inset) of the central area indicates the arrangement of the dipolar sources in this region.

Background activity was modeled by assigning a stochastic amplitude time curve to each of the dipolar sources in the cortex (except for the one source which served as spike generating source). A realistic three compartment boundary element model served as forward model. 102 MEG and 63 EEG sensor positions were used.

3 Results

We found that, with a realistic background activity, EEG is more sensitive to radially oriented spikes, while MEG is more sensitive to tangentially oriented spikes (Fig. 2). A selective increase in radial background activity lowers the sensitivity of EEG for radial spikes, while a selective increase in tangential background activity lowers the sensitivity of MEG for tangential spikes.

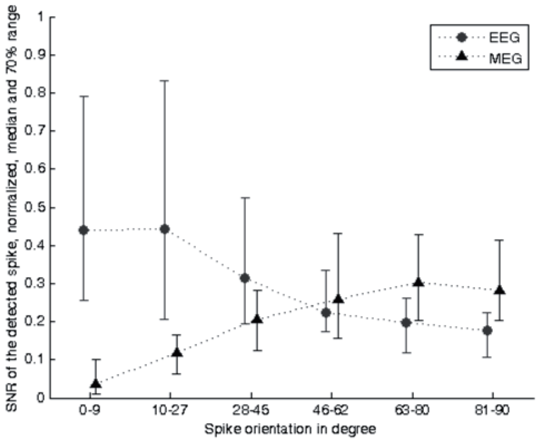

Figure 2 Medians and 70 percent ranges of the normalized SNR of all individuals, all traces in all hemispheres and regions plotted over the binned dipolar source orientation (radial – 0 degree; tangential – 90 degree).

4 Conclusion

Our results provide a possible explanation for the clinical fact that sometimes spikes are better visible in EEG and sometimes better in MEG.

5 References

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