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CASE REPORT

Source estimation of epileptic activity using eLORETA kurtosis analysis

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SUMMARY

Exact low-resolution brain electromagnetic tomography (eLORETA) is a technique for three-dimensional representation of the distribution of sources of electrical activity in the brain. Kurtosis analysis allows for identification of spiky activity in the brain. To evaluate the reliability of eLORETA kurtosis analysis, the results of the analysis were compared with those of equivalent current dipole (ECD) and synthetic aperture magnetometry (SAM) kurtosis analysis of magnetoencephalography (MEG) data in a patient with epilepsy with elementary visual seizures in a 6-year follow-up.

The results of electroencephalography (EEG) eLORETA kurtosis analysis indicative of a right superior temporal spike source partially overlapped with MEG ECD/SAM kurtosis results in all recordings, with a total overlapping at the end of the follow-up period. Overall findings suggest that eLORETA kurtosis analysis of EEG data may aid in the localisation of spike activity sources in patients with epilepsy.

BACKGROUND

Elementary visual seizures are characterised by visual hallucinations of amorphous elementary images, including bright coloured spots.[1] Although they are common in occipital lobe epilepsy, some of them are caused by temporal lobe epilepsy. Using magnetoencephalography (MEG), we previously reported a patient with epilepsy exhibiting elementary visual seizures of temporal lobe origin, as indicated by equivalent current dipole (ECD)[2] and automated spike detection with synthetic aperture magnetometry kurtosis (SAM-kurtosis) analysis.[3] There was a high spatial concordance between the source localisation of interictal spikes using these two analysis methods. We have also demonstrated that SAM-kurtosis is useful for detection of epileptogenic areas in patients with focal cortical dysplasia.[4] Although electroencephalography (EEG) is more widely used in the clinical scenario for epilepsy diagnosis, this kind of automated data analysis for spike source localisation has rarely been applied to EEG data.

Exact low-resolution brain electromagnetic tomography (eLORETA) is a method devised by Pascual-Marqui (1994) for depicting the distribution of electrical activity sources in the brain.[5] This is often applied to EEG data to identify sources of both abnormal oscillatory activity and aberrant functional connectivity in neuropsychiatric disorders.[6–9] Recently, the kurtosis analysis has been implemented in eLORETA software. Kurtosis is a measure of the relative sharpness of curves. Thus, it is assumed that kurtosis analysis of time series signals using eLORETA will allow us to estimate EEG sources of spike activity in patients with epilepsy.[10] In this study, we aimed to evaluate the reliability of eLORETA kurtosis analysis. For this purpose, we applied this analysis to the EEG recordings of a patient with temporal lobe epilepsy with elementary visual seizure, and compared the results to those obtained from this patient in our previous MEG study using ECD/SAM-kurtosis analysis.

CASE PRESENTATION

The patient is a 32-year-old man with no history of disease. At age 25 (year X), he started to experience elementary visual seizures, characterised by bright coloured spots moving within both visual fields with secondary generalisation. His EEG recording showed focal spike activity. He was diagnosed with epilepsy and treated with phenytoin (200 mg/day) in our outpatient clinic. After a temporal improvement with medication, the seizures recurred 1 year later (year X+1) not associated with loss of consciousness or secondary generalisation. At that time, seizure frequency was one every 2 months. The phenytoin dose level was increased to 300 mg/day. In year X+3, the frequency of seizures decreased to about twice a year, and in year X+4 both elementary visual seizures and secondary generalised seizures ceased. The medical examination revealed no neurological abnormalities, and the MRI scanning showed bilateral cerebellar hypoplasia, with no brain cortical lesions. During the follow-up, five EEG recordings were analysed (onset, year X+2, X+3, X+4, X+6). EEG data were obtained using a 19-channel digital EEG system (EEG-1100, Nihon Kohden), with the electrodes arranged according to the international 10–20 system (Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, Fz, Cz and Pz). For analysis, EEG resting-state data with eyes closed were used (sampling rate 500 Hz). Each EEG session lasted about an hour, and all 30 s artefact-free periods containing spikes or sharp waves obtained during visual inspection of the data were used for eLORETA kurtosis source localisation analysis. Spike activity in eLORETA yields large positive kurtosis values while normal cortical activity is associated with low kurtosis values.

MEG data in this patient were recorded using a 64-channel whole head MEG system (NeuroSQUID

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Model 100, CTF Systems Inc). Four MEG sessions of 30 min duration at rest with eyes closed (Year X+2, X+3, X+4, X+6) were obtained on the same day of the follow-up EEG recordings. The sampling rate was 250 Hz. All MEG spikes were used for ECD analysis. ECD with consistency between actual and estimated values of magnetic field >90% was adopted. In addition, MEG data were also used for SAM-kurtosis analysis, revealing the current source density distribution of spike components with high kurtosis.

INVESTIGATIONS

Head MRI: Hypoplasia of the bilateral cerebellar cortices.

EEG: Interictal spikes in the right temporal region (T4).

DIFFERENTIAL DIAGNOSIS

Related epilepsy with secondarily generalised tonic-clonic seizure (GTCS).

TREATMENT

Start with phenytoin (200 mg/day).

Currently, the treatment with phenytoin (300 mg/day).

OUTCOME AND FOLLOW-UP

The results of the visual inspection of EEG waveforms in the initial recording revealed spikes with phase reversal at electrode T4, indicating a right temporal source of epileptiform activity. At year X+2, a total of nine MEG spikes were found valid for ECD source localisation. The results of the combination of ECD and SAM-kurtosis analysis indicated that MEG spikes were distributed over the right fusiform, inferior temporal and middle temporal cortex (figure 1A, top). eLORETA kurtosis analysis showed high kurtosis values in the right temporal area, with maximal kurtosis value of 82.22 in the middle temporal cortex (figure 1A, bottom). At year X+3 of the follow-up, ECD analysis identified MEG spikes in the right middle temporal and superior temporal cortex, with the largest cluster in Heschl's gyrus. MEG SAM-kurtosis analysis estimated the spike source in the superior temporal cortex, including Heschl's gyrus. eLORETA kurtosis analysis found sources of high kurtosis values over the superior temporal cortex, including Heschl's gyrus, as well as in the inferior parietal cortex, with maximal kurtosis value of 80.12. At year X+4, MEG ECD/SAM-kurtosis results indicated that the spike source was localised in the right temporal lobe, specifically in the Heschl's gyrus (figure 1B, top). The results of eLORETA kurtosis localised the spike source in the right Heschl's gyrus and the adjacent inferior parietal cortex; the maximal kurtosis value being of 100.41 (figure 1B, bottom). The last follow-up evaluation at year X+6 revealed that both MEG ECD/SAM-kurtosis and EEG eLORETA kurtosis localised the source of spike activity in the right Heschl's gyrus (figure 1C). The maximal eLORETA kurtosis value was of 10.20 in this cortical source.

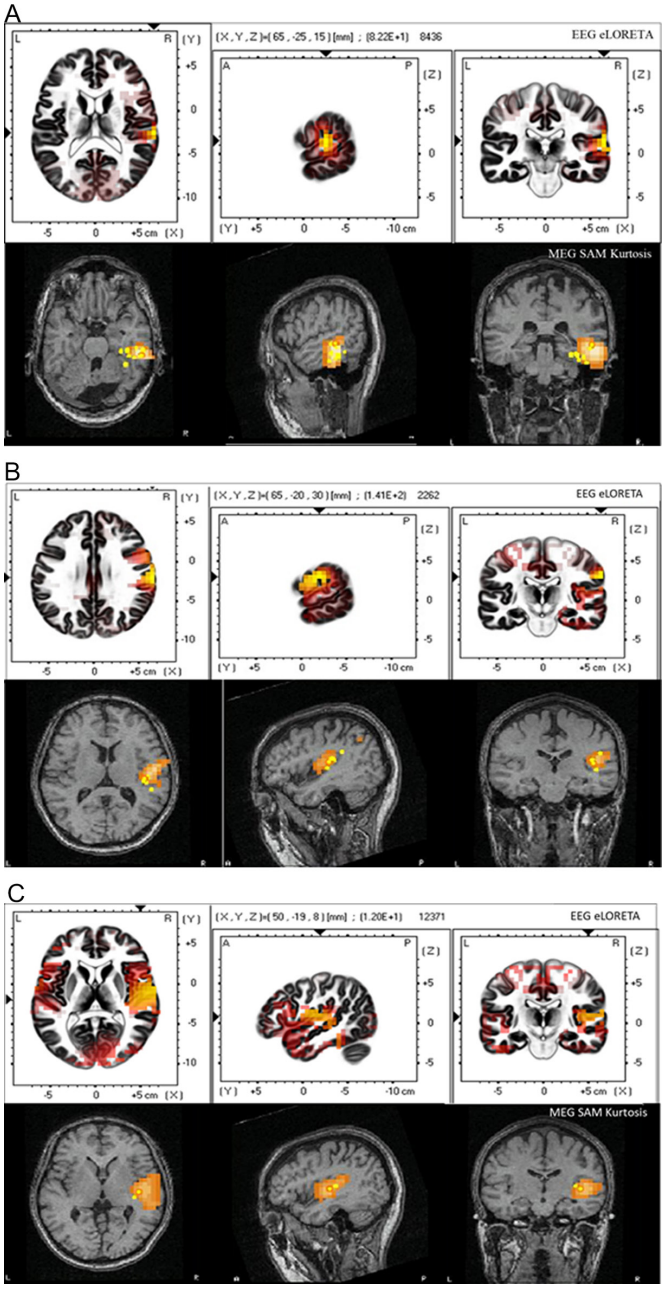

Figure 1 Results of magnetoencephalographic (MEG) dipole analysis and synthetic aperture magnetometry (SAM) kurtosis analysis (upper column) and electroencephalographic (EEG) exact low-resolution brain electromagnetic tomography (eLORETA) kurtosis analysis (lower column) at different moments of the follow-up. In MEG data, the yellow dots represent dipole locations, and orange-coloured areas, the distribution of spikes determined by SAM kurtosis. In EEG, the yellow-coloured areas indicate cortical regions with high kurtosis values.

DISCUSSION

In this study, the results of eLORETA kurtosis source localisation of spike activity in EEG recordings were compared with those of ECD and SAM-kurtosis analysis of MEG data in a patient with temporal lobe epilepsy with elementary visual seizures. By 6-year follow-up, the localisation of spikes measured with ECD was highly concordant with the distributed sources of spikes determined by SAM-kurtosis analysis of MEG recordings throughout the follow-up. The results of EEG eLORETA kurtosis analysis indicative of a right superior temporal source of spikes partially overlapped with MEG ECD/SAM-kurtosis results in years X+2, X+3 and X+4, and showed a total overlapping at the end of the follow-up period.

Elementary visual seizures are often associated with localisation-related epilepsy of occipital origin. In about 6%–13% of cases, these symptoms relate to temporal lobe epilepsy, like in the case presented here. An interesting study of ictal MEG with simultaneous EEG recording in a patient with elementary visual seizures during status epilepticus also found that the

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seizures arose from the superior temporal gyrus.[11] Although there was no complete overlapping of EEG and MEG results in our study, the images of kurtosis values provided by eLORETA identified the right temporal cortex as the generator of epileptic activity in this patient. The lack of a complete overlapping could be attributed, at least in part, to the fact that MEG analyses for source localisation of spikes are performed fusing the data with the patient's MRI whereas EEG eLORETA uses an anatomical brain template.

To our knowledge, the kurtosis function for EEG detection of spikes has not been used. Nevertheless, other studies using 'excess kurtosis' analysis in MEG have provided evidence indicating that neuroimaging of kurtosis values is useful to localise intrinsically epileptogenic zone in patients with refractory epilepsy due to focal cortical dysplasia[12] or tuberous sclerosis complex.[13]

Learning points

- Our findings suggest that exact low-resolution brain electromagnetic tomography kurtosis analysis of EEG data may aid in the identification of spike activity sources in patients with epilepsy.
- Further analysis of kurtosis in patients that undergo epilepsy surgery will be necessary to validate the use of this method for spike source localisation.

Contributors SI contributed as the first author to the paper and conducted EEG analysis as outlined in the paper. RI was as a part of the psychiatry team caring for the particular patient. LC was the neurological consultant leading in the care of this patient. RDP-M developed analysis software.

Competing interests None declared.

Patient consent Obtained.

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