Measurement and Quantification of Interictal and Postictal DC Magnetic Field Shifts in Unilateral Temporal Lobe Epilepsy

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Introduction

Unilateral low frequency activity in the region of the ictal onset is commonly found in patients with focal seizures arising from the temporal lobe (temporal lobe epilepsy or TLE) and may be best observed in the postictal period [1,2]. We hypothesized that magnetic field shifts should be present in TLE patients, particularly when DC recordings are used, and might provide information that could be used to support the diagnosis of epilepsy. Traditional DC magnetic field recordings are very time consuming, making it difficult to obtain DC-MEG data free of artifacts due to the subject becoming restless and changes in the state of awareness of the subject. Hence, there is a need for techniques which can be used to record DC field changes quickly. One such technique which we developed is presented here. Nine control subjects were studied on three consecutive days and 9 subjects with unilateral TLE were studied between (interictal MEG) and within 24 hours (postictal MEG) of a seizure. In each session, 7 channel DC-MEG recordings were obtained from both temporal lobes. We hypothesized that the post-ictal to interictal difference in the DC field shifts occuring in the epileptic temporal lobe of TLE patients would be greater than the difference for the "normal" temporal lobe and also greater than the day-to-day changes in DC field shifts occurring in control subjects. This hypothesis was based on the fact that epileptic brain tissue exhibits large depolarizations and hyperactivity during seizure and these in turn would change ionic concentrations leading to changes in DC potentials. These studies were aimed at determining whether this technique can be used to accurately detect the DC field changes due to seizure activity and to determine if the DC field changes occurring in TLE patients are different from the day-to-day changes occurring in control subjects.

Methods

Nine control subjects and 9 TLE subjects were used in this study. DC-MEG recordings were performed on these subjects using a seven channel BTi 607 neuromagnetometer in a shielded room. The technique used for these recordings consisted of raising and lowering the subject with respect to the probe. Polystyrene head holders were custom made for each subject and these were used as positioning devices. Fig. 1 is a schematic representation of the head holder. The head holder was placed on a non-magnetic platform in the shielded room. The position of the head holder on the platform was kept the same in all the runs for each subject. This was done by placing the head holder on a wooden base with wooden pins on the bottom. The wooden base was placed on a non-magnetic base plate with holes in it for the pins. This set up helped to position the subject in the same position in each run. The neuromagnetometer probe and the non-magnetic platform were also set in the same position with respect to the room and each subject in each run. Fig. 2 shows the experimental setup. The subject was degaussed using a video tape eraser and the subject's head was wet with water and sprayed with Anti-static spray (STATX brand, manufactured by RTW Int. Corp). The subject was asked to lie on the non-magnetic platform with head in the head holder.

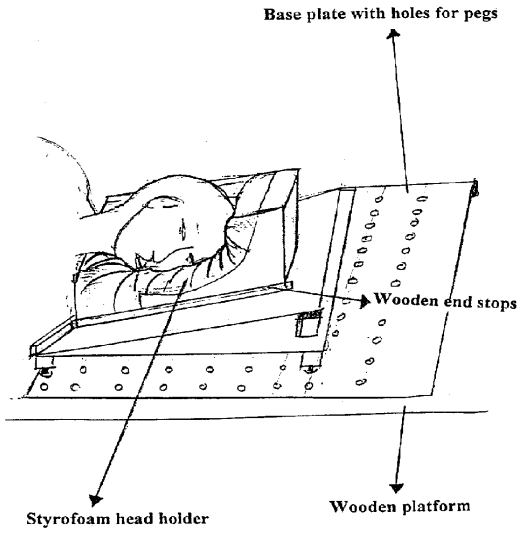

Fig.1. Schematic representation of polystyrene headholder

The platform was then raised until the probe was close to the head without touching it. This raising operation was done using a brass crank. The distance of the head from the probe was noted and this was designated the 'up' position. The subject was then lowered using an air driven piston, which moved the subject's head a distance of 2.5 cm from the probe. This position was noted and designated the 'down position. The above procedure of fixing the 'up' and 'down' position was done for each

subject during the first run. The 'up' and 'down' positions were kept the same for every run for each subject. Once the 'up' and 'down' positions were fixed the raising and lowering operations were performed by the air-driven piston during the subsequent runs.

The orientation of the neuromagnetometer probe over the subject's head was such that the center channel (channel 1) was directly over the T3 or T4 position, depending on the temporal lobe being studied. A total of 120 seconds of DC-MEG data was collected during each run, this was done as follows, with the subject in the 'down' position 12 seconds of DC data were collected, then the platform was raised to the 'up' position and 12 seconds of data were collected in this position, and 5 such epochs of 12 seconds were collected in each position. The entire procedure described above was repeated on three consecutive days for each control subject and on two different days for TLE subjects. The time points for the TLE measurements were interictally and within 24 hours of a seizure. Both temporal lobes were studied for subjects from both groups (control and TLE).

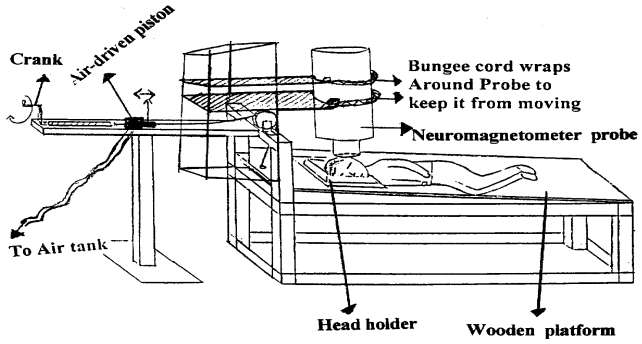

Fig.2. Experimental setup showing non-magnetic platform, head holder, apparatus to lock probe in position, crank, air-driven piston and probe.

Data Analysis

All DC-MEG data were analyzed using HP 694A multiprogrammer. Data were sampled at 130 Hz and the high and low pass filters were set at 0 and 50 Hz respectively. The DC magnetic field shift for each run, for each temporal lobe, for each subject was calculated by taking the difference between the DC-MEG data collected in the 'up' and the 'down' positions. The five differences thus calculated for each run for each temporal lobe were averaged to get a value DC shift for each channel. These average values per channel were in turn averaged to get a DC shift value for the temporal lobe. These values were further subjected to the following comparisons:

- The difference between the interictally and post-ictally measured DC magnetic field shift was expressed as a percentage of the field shift measured interictally (baseline). For control subjects the difference between field shift measured on day 1 and day 3 was expressed as a percentage of day 1 (baseline) measurement.
- The difference between the DC field shifts measured interictally and post-ictally in TLE patients from the epileptic temporal lobe and the difference measured from the normal temporal lobe was expressed as a ratio with the larger difference being the denominator. The difference between DC field shifts measured on day 1 and day 3 in control subjects from left temporal lobe and the difference measured from the right temporal lobe was expressed as a ratio. Thirty six different ratios were calculated for control subjects. This was done by taking the left temporal lobe difference as the denominator in seven subjects and right temporal lobe difference as the denominator in two subjects. This was done because in the TLE subject group seven subjects had left temporal lobe focus and 2 had right temporal lobe focus. Each of the 36 ratios was compared to the average TLE ratio.
- The magnitude of the DC field shift calculated interictally and post-ictally in TLE subjects from both temporal lobes was compared to measurements from control subjects.
- Comparison of the AC activity from the 2 subject groups were made by comparing the power in 5 frequency bands (1-4 Hz, 4-8 Hz, 8-12 Hz, 12-19 Hz, 19-30 Hz).

Results

- The percentage change from the baseline in the DC magnetic field shift in TLE subjects was higher on the epileptic temporal lobe than on the normal temporal lobe (See Fig. 3a). It was also higher than the change measured in controls. Both these differences were statistically significant (Wilcoxon test)
- The percentage change from baseline (day 1) in the DC magnetic field shift in control subjects was higher in the right temporal lobe; however, this difference was not statistically significant (See Fig. 3b).
- The ratio of the interictal and postictal DC field shift differences measured from the normal temporal lobe and that from the epileptic temporal lobe in TLE subject was less than 1 (See Table 1).
- The ratio of the day 1 and day 3 DC field shift difference measured in controls from one temporal lobe and the difference measured from the other temporal lobe was greater than 1 (See Table 1).

- The magnitude of the DC field shifts measured in TLE subjects did not differ from those measured in control subjects (See Table 2).
- The comparison of the power in the five frequency bands shows that the power in the 1-4 Hz band post-ictally in TLE subjects on the epileptic side is higher than the postictal 1-4 Hz power on the normal side (See Fig. 4a).
- The comparison of the power in control subjects in the five frequency bands measured from one temporal lobe did not differ from that measured from the other temporal lobe (See Fig. 4b).

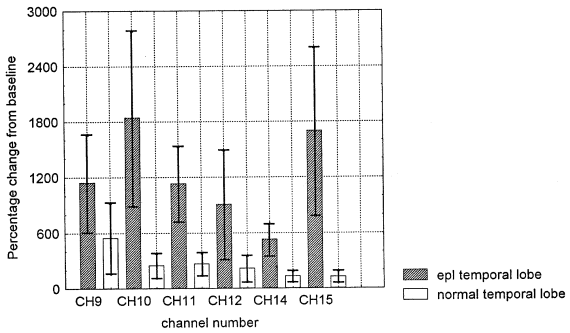

Fig. 3a. The percentage change from baseline in TLE subjects. Epileptic temporal lobe compared to normal lobe.

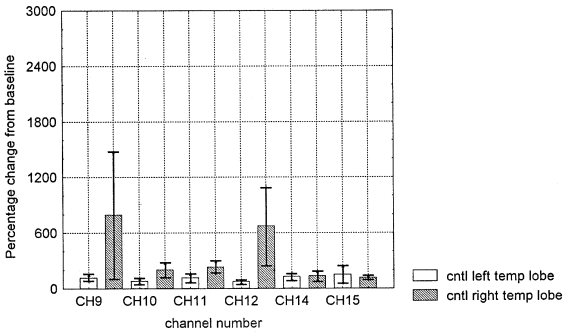

Fig. 3b. Percentage change from baseline in control subjects, right temporal lobe compared to left lobe

Descriptive Statistics for the Ratio in TLE subjects and Range of Ratios for the Control Subjects

Statistics	TLE subjects	Range for Controls
Mean	0.518	1.046-2.756
Std Dev	0.364	1.034-2.438
Median	0.593	0.759-1.944
Min	0.023	0.141-0.759
Max	0.994	3.362-7.068

Table 1. Comparison of the ratios of day-to-day difference in DC shift for one temporal lobe and the difference for the other lobe. TLE ratios compared to control ratios. TLE ratios are all less than 1 and do not lie within the range of ratios for control subjects.

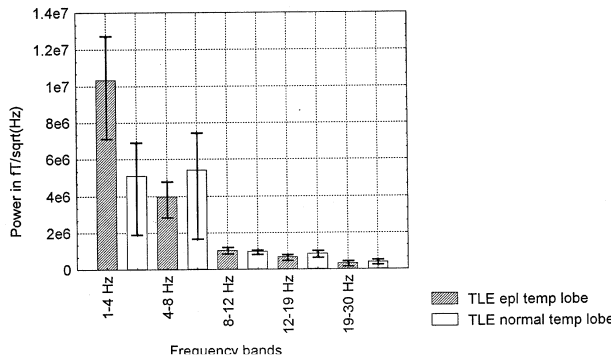

Fig. 4a. Comparison of the epileptic temporal lobe and normal temporal lobe, interictal to post-ictal difference in power in the five bands.

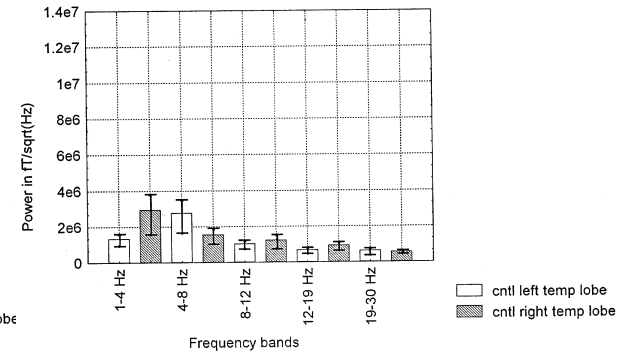

Fig. 4b. Comparison of the right temporal lobe and left temporal lobe, day 1 to day 3 difference in power in the five bands.

Epileptic Lobe DC shift amplitude (in fTesla)—post-ictal of TLE subjects vs

DC shift amplitude from day3 of Control subjects

Descriptive statistics	TLE subjects epileptic Lobe	Control Left Lobe	Control Right Lobe	Control Average
N	9	9	9	9
Mean	4066.8	812.5	1437.3	1124.9
Std Dev	5600.3	402.9	1298.7	692.7
Median	1667.2	712.3	1078.7	973.8
Range	348.2-17010.1	250.3-1528.0	179.1-3689.4	214.7-2234.0
p- value for TLE Vs control		0.0521	0.2893	0.1853

Table 2. Comparison of magnitude of DC field shift in Control subjects and TLE subjects.

Discussion

This pilot study shows that focal DC magnetic field shifts occur as a result of focal seizures and the technique developed here can be used to measure these field changes. If these findings are confirmed by further studies using large array magnetometers, this technique may have a clinical utility in the assessment of patients following presumed epileptic seizures. The day-to-day variability in the DC field shift measurement in control subjects was found to be larger than was expected based on previous data [3]. This variability in control subjects was larger on the right temporal lobe. The reason for this has yet to be determined. The DC field shift changes signs from one day to the next in measurements from both subject groups, though this sign change was seen more often in TLE subjects, mainly on the epileptic temporal lobe. Since, these sign changes occur in control subjects, it may be due to dynamic changes in neurophysiology which may in some way be amplified in TLE subjects.

References

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Acknowledgments

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