MAGNETOMETER OUTPUT

TIME

SHORT

LONG
Two types of magnetic DC situations:

- Short DC, where the subject does not move, but his state alters quickly.

- Long DC, where the subject must move in-and-out of the detector, while his state remains steady.
Dog away

Before occlusion

$4 \times 10^{-7}$ gauss

Interrupted dc

S–T segment shift

Baseline shift

Two minutes after occlusion
Fig. 3. Arrow pattern over the forearm of two normal subjects. Solid arrows are over the outer (viewer's) side of the arm, broken arrows over the inner side. The patterns are characteristic of these subjects and indicate the wide variation from subject to subject. The dcMF of (A) was often absent, and the pattern shown could always be induced by 30 sec of light twisting and rubbing against the dewar tail. The pattern of (B) was usually present without this manipulation.
FIG. 4. The dcMF over the thigh of a dog, after subcutaneous injection of 0.5 ml of 3 M KCl at 0-time. The field gradient is seen to increase by a factor of about 60 from the normal (preinjection) level, measured to be in the range 40–70 nG/cm.
Summary of DC over the human body

- DC from extremities, due to changes in K-ion concentration gradient over long muscle fibers
- DC from abdomen, from cold reflex, and GI activity
- DC from scalp (hair follicles)
- Otherwise torso is relatively clean -- short muscle fibers
- DC from injured heart
- I never got to search the brain proper (too complicated)
Crank → Air-driven piston

Bungee cord wraps around probe to keep it from moving

Neuromagnetometer probe

To Air tank

Head holder

Wooden platform
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 postictal to interictal difference in the DC field shifts occurring 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.
Spreading depression

Romualdo José do Carmo

Spreading depression (SD) is an experimental reaction to local stimulation of the gray matter, originally observed in the cerebral cortex of vertebrates, and characterized by a depression of the tissue electrical activity and excitability, maximally deep for a period of 1–2 min. It appears first at the stimulated site and spreads out in all directions, so that increasingly distant areas undergo successively a similar temporary depression. The spread which proceeds at a velocity of a few millimeters per minute, is self-sustained, and at any site, SD is followed by an absolute refractory period of 1 min or so. Two or more SDs can be initiated at the same time in different sites; when the advancing front of one comes into the refractory period of
MODELLING THE SPREADING CORTICAL DEPRESSION (SCD) WAVEFRONT

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Spreading Cortical Depression (SCD) is a wave of depolarization that spreads across the cortex at 2-5 mm/min and is followed by a 5-10 minute reduction in EEG activity. It is assumed that SCD is involved in the pathophysiology of migraine. We present a new modeling and visualization technique for the spread of excitation on realistic brain surfaces. The usefulness of the technique is demonstrated on a rat brain which has been segmented from a 3D magnetic resonance image (MRI) data set. With the help of this methodology it is possible to create patient specific models to better understand the mechanisms of SCD.

INTRODUCTION

Leao first discovered Spreading Cortical Depression (SCD) of the EEG in the rabbit brain over 50 years ago\(^1\). Leao found that reduction of the normal electrical activity of rabbit neocortex could be induced by a variety of external stimuli\(^1\) including KCl application\(^2\). Leao observed that the depressed activity begins in one hemisphere, at the stimulus site, and spreads slowly in all directions. He also observed vascular changes (pial arterial and venous dilatation) that occurred simultaneously with the onset of spreading electrical depression and followed closely the pattern of that depression\(^3\). This led him and others to speculate about the possible involvement of SCD in the pathophysiology of migraine\(^4,5\).
The modulation device: Scissors lift construction and measurement geometry
Construction of the horizontally movable bed.
Non-invasive long-term recordings of cortical ‘direct current’ (DC–) activity in humans using magnetoencephalography

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Received 8 July 1999; received in revised form 5 August 1999; accepted 5 August 1999

Abstract

Recently, biomagnetic fields below 0.1 Hz arising from nerve or muscle injury currents have been measured non-invasively using superconducting quantum interference devices (SQUIDs). Here we report first long-term recordings of cortical direct current (DC) fields in humans based on a horizontal modulation (0.4 Hz) of the body and, respectively, head position beneath the sensor array: near-DC fields with amplitudes between 90 and 540 fT were detected in 5/5 subjects over the auditory cortex throughout prolonged stimulation periods (here: 30 s) during which subjects were listening to concert music. These results prove the feasibility to record non-invasively low amplitude near-DC magnetic fields of the human brain and open the perspective for studies on DC-phenomena in stroke, such as anoxic depolarization or peri-infarct depolarization, and in migraine patients. © 1999 Elsevier Science Ireland Ltd. All rights reserved.
Fig. 1. Auditory evoked magnetic fields over the left auditory cortex (diameter of the circular sensor array: 210 mm; solid isofield lines: magnetic flux leaving head, dashed: entering, isofield step spacing: 4 ft). (a) Reconstructed near-DC magnetic field map derived as the difference of music – silence periods (subject 1). (b) N100m response to a squarewave toneburst (same subject). (c) Estimated source locations of the near-DC field (●) in relation to the N100m (O) source position (mean of five subjects ± SEM).
Magnetometry of injury currents from human nerve and muscle specimens using superconducting quantum interferences devices

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Received 11 December 1998; received in revised form 11 January 1999; accepted 11 January 1999

Abstract

Acute lesions of polarized membranes lead to slowly decaying ('near-DC') injury currents driven by the transmembrane resting potential gradient. Here we report the first recordings of injury-related near-DC magnetic fields from human nerve and muscle specimens in vitro using Superconducting Quantum Interference Devices (SQUIDs) operated in a conventional magnetically shielded room in a clinical environment. The specimen position was modulated sinusoidally beneath the sensor array by a non-magnetically fabricated scissors lift to improve the signal-to-noise ratio for near-DC fields. Depending on the specimen geometry the field patterns showed dipolar or quadrupolar aspects. The slow decay of human nerve and muscle injury currents was monitored for several hours from a distance of a few centimeters. Thus DC-magnetometry provides a sensitivity which might allow the remote detection of injury currents also in vivo. © 1999 Elsevier Science Ireland Ltd. All rights reserved.
Hyperventilation-induced human cerebral magnetic fields non-invasively monitored by multichannel ‘direct current’ magnetoencephalography

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Received 4 April 2000; received in revised form 12 May 2000; accepted 15 May 2000

Abstract

Self-paced hyperventilation (HV) induces slow cerebral magnetic field changes which were monitored and mapped continuously over 15 min using 49-channel DC-coupled (‘direct current’) magnetoencephalography (DC-MEG) based on a modulation technique. In nine/nine healthy subjects HV caused an increase (range: 1.1–6.2 pT) of the mean global DC-MEG field strength which slowly decayed after HV termination (mean time constant: 2 min). The complex HV-related field patterns were distinctly different from mainly dipolar somatosensory evoked field maps (N20m) in four/four subjects. Thus, current sources in the primary somatosensory cortex need not regularly dominate DC-field changes as had been previously considered. Rather, DC-MEG enabled the monitoring of a widely distributed HV-induced enhanced cortical excitability which may serve as model to study epileptic or post-anoxic cerebral hyperexcitability.
SQUID MEASUREMENTS OF HUMAN NERVE AND MUSCLE NEAR-DC INJURY-CURRENTS USING A MECHANICAL MODULATION OF THE SOURCE POSITION

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Abstract—Near-dc ionic currents arise after injury of nerves. The detection of their concomitant magnetic fields requires new techniques, to be applied in the growing field of biomagnetic measurement technology. The mechanical modulation of the source-to-detector distance enables monitoring of such slowly varying magnetic fields. In this report we describe technical details of the modulation device, including signal processing and system performance. The functionality of the device is demonstrated with an investigation on an in vitro human nerve specimen and with an in vivo investigation, performed with a patient undergoing a diagnostically indicated muscle biopsy. © 1999 Elsevier Science Ltd. All
Spatial and temporal distribution of magnetic field due to injury currents in Vicia faba plants

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1 Introduction

Different types of wounds on plants cause measurable changes in the biochemical and biophysical behaviour of plants. Among them are also electrophysiological changes. Studies using extracellular and implant in a suitable ionic solution. This method has been used in the past to monitor electrical activity in animal cells, which also respond to injury with electrical activity \cite{6, 7}. The measurements aim to provide information on electrical propagation, injury-induced currents, and response of currents in wound...
Near-DC magnetic fields following a periodic presentation of long-duration tonebursts.

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OBJECTIVES: The purpose of this study was to determine the time course of low-frequency (<0.1 Hz) magnetic field components evoked by long-duration tonebursts. The following two questions were of central interest. Does the sustained field (SF) show adaptation as described before for the sustained potential (SP)? How does the field amplitude return to the pre-stimulus baseline after stimulus offset? METHODS: Neuromagnetic measurements were done with a 37-channel first-order gradiometer system. The stimulus was a 1 kHz toneburst of 10 s duration presented at fixed 20 s intervals. The averaged data (high-pass filtered, 0.03 Hz cut-off) were analyzed using the model of an equivalent current dipole with time-invariant location and orientation (fixed dipole).

RESULTS: In the grand average of the subjects with the best signal-to-noise ratio, the SF exhibited adaptation with a time constant of 3.6 s. After stimulus offset, the amplitude of the dipole moment dropped to a lower level within 300 ms and decayed exponentially to the baseline thereafter (time constant 2.7 s). CONCLUSIONS: A two-component model is proposed: One component roughly follows the envelope of the stimulus, the other behaves like a leaky integrator. A better understanding of near-DC fields appears to be crucial for the understanding of the relationship between magnetoencephalography and other functional imaging techniques like functional magnetic resonance imaging and positron emission tomography.
Intracranial EEG with very low frequency activity fails to demonstrate an advantage over conventional recordings.

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PURPOSE: Conventional scalp and intracranial EEG is recorded within a limited band of frequencies (0.3-70 Hz) based on the premise that clinically relevant cerebral activity occurs within this frequency range. Ikeda et al. recently demonstrated focal very low frequency activity (VLFA), <0.3 Hz, at seizure onset for both intra- and extracranial recordings. The purpose of this investigation was prospectively to study VLFA during seizures in intracranial recordings to determine whether activity in this frequency range provides useful information regarding localization of seizure onset and spread. METHODS: Patients undergoing intracranial electrode implantation were studied by using a high-pass filter of 0.01 Hz. The timing, location, and pattern of seizure onset were first determined by using a digital high-pass filter of 0.3 Hz (conventional seizure onset). Seizures were then reviewed without digital filters and the presence of VLFA recorded, along with its timing and location. RESULTS: Forty-seven seizures were recorded in four patients. VLFA was not observed in 29 seizures and, in one other case, VLFA occurred simultaneous with movement. Of seizures with VLFA (n = 17), the timing and location of VLFA were not consistent with those of conventional seizure onset or propagation. CONCLUSIONS: Our study failed to demonstrate any clinical advantage of intracranial telemetry recordings with a high-pass filter of 0.01 Hz over conventional recordings with regard to determining the timing and location of seizure onset and propagation.
Very slow EEG responses lateralize temporal lobe seizures
An evaluation of non-invasive DC-EEG

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Abstract—Background: This study tested the idea that very slow EEG responses (direct current [DC] potential shifts) could be detected noninvasively during temporal lobe (TL) seizures, and that these shifts give lateralizing information consistent with that obtained by other methods. Methods: Seven patients with TL epilepsy (TLE) were recorded with scalp DC-EEG technique at bedside. All recordings were performed simultaneously with conventional EEG (scalp in five, and intracranially in two; two patients with scalp recordings were recorded intracranially later). Seizures in five patients originated in the mesial TL. Ictal DC shifts were evaluated by comparing them to the temporal evolution of ictal discharges, and by comparing the laterality of these shifts to the side of seizure onset defined by routine EEG and other presurgical diagnostic tests. Results: All seizures (35/35) were associated with negative DC shifts at temporal derivations (30 to 150 μV relative to vertex), beginning at the electrical seizure onset, and lasting for the whole seizure. In eight seizures (five patients) with documented mesial TL onset, the polarity of the DC shift was initially positive followed by a negative one after lateral spread of seizure activity. In all cases, the side of the EEG shift agreed with other diagnostic tests, and, at times, was more clearly lateralized than the conventional scalp EEG. Conclusions: DC-EEG recordings are practical and achievable at the bedside. Ictal DC shifts are consistently observed in scalp recordings in TL seizures, and reliably lateralize them. This method may hold promise in reducing the need for invasive monitoring in patients with TLE where other noninvasive tests are equivocal.

NEUROLOGY 2003;60:1098–1104
What DC work can we do here?

- Certainly we can do short DC; the subject does not move during an on-off event
- We cannot do long DC (more interesting) because of our floor
- Should we go to the trouble of altering the floor? **USERS SHOULD DECIDE!**