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Non-invasive evaluation of electrical brain activity: effects of non-medicative treatment and subject's state

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Introduction. The electroencephalogram (EEG) and evoked potentials (EPs) are widely used in psychiatry. Thus, it is important to standardize recording conditions according to instructions, arousal and attention levels of the subject. Also, it is important to evaluate the effect of non-pharmacologic treatment (electroconvulsive therapy (ECT) and transcranial magnetic stimulation (TMS)) on EEG and EPs. In this paper, an overview of researches, conducted in the above mentioned directions in Lithuania, is given.

Materials and methods. EEG was recorded using standard protocols; P300, P50 and auditory steady-state responses (ASSR) were elicited. 44 schizophrenic patients, 25 depressive patients and 136 healthy subjects were investigated. Effects of ECT treatment, 10 Hz TMS procedure, and varying attention and arousal levels on EEG/EPs were investigated.

Results. ECT had no negative impact on P300; alongside with clinical response, normalization of P300 parameters occurred. It was related to subject's age and autonomic nervous system response during the treatment. A single 10 Hz TMS procedure produced a profound increase in the delta power of background EEG. In lower arousal level conditions, higher and more precise P50 potential, ASSR and background alpha power were observed. During distraction task performance, reduced gamma band response and ASSR, and increased background gamma power were observed.

Conclusions. During the treatment course of ECT it is recommended to evaluate P300 potential changes and to monitor subject's indices of the autonomic nervous system function, as these are related to clinical efficiency. Passively elicited auditory responses should be registered during low arousal unfocused attention conditions when the most precise responses of the highest amplitude are registered.

Key words: electroencephalogram, evoked potentials, optimal recording conditions, electroconvulsive therapy, transcranial magnetic stimulation

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INTRODUCTION

Electroencephalogram (EEG) is the sum of extracellular currents that are noninvasively recorded from the surface of the human head. EEG changes that are related to the occurrence of an event are called evoked potentials (EPs) (1). Neural activities generate the flow of electric current in the brain, and all processing occurs as a spatiotemporal alteration in global current. The momentary electric field, i. e. the electric potential distribution on the scalp, shows us the sum of all currents at any given moment in time. In a sense, the EEG is the recording of these electric field potentials in discrete scalp positions (2). The EEG/EP recording procedure is rather routine and highly standardized in respect to electrode placement, recording conditions and equipment. EEG and EPs are used in psychiatry to confirm diagnoses, to evaluate safety and efficiency of the treatment (3). As the method is widely used, it is important to evaluate factors that are common for clinical practice and might affect the results. It is important to know how the state of the subject (arousal and attention levels) affects EEG and EPs. Another important issue is to apply EEG and EPs for evaluation of treatment safety and efficiency. Effects of pharmacologic treatment are widely investigated (3). However, the effects of non-pharmacologic therapies, that are applied in psychiatry (electroconvulsive therapy (ECT) and transcranial magnetic stimulation (TMS)), on electrical brain activity are unknown (4–6).

The aim of the current paper is to overview researches that focused on the implementation of EEG and EPs to improve clinical testing of the patients in the abovementioned areas. Summarized studies are the first step towards wider implementation of EEG and EPs in a clinical practice in Lithuania. Moreover, being published in peer-reviewed international journals, the results proved being of interest for wider international community. During the period of 2005–2012, several researches aiming at evaluation of the effects of non-pharmacologic treatment of psychiatric disorders (ECT and TMS) and subject's state (arousal and attention level) on EEG and EPs were conducted at the Department of Neurobiology and Biophysics in collaboration with the Department of Electrophysiological Treatment and Investigation Methods at the Republican Vilnius Psychiatric Hospital, the Centre for Nervous Diseases at the Psychiatry Department of Rostock University, Cognitive Research Unit and Ballerup Psychiatric Centre at Copenhagen University and Psychology Department at Mykolas Romeris University. EEG was chosen as an objective non-invasive method that allows evaluation of electrical brain activity. Comprehensive data analyses were performed, covering both time-voltage and time-frequency domains.

MATERIALS AND METHODS

Subjects

Overall, 44 schizophrenic patients, 25 depressive patients and 136 healthy subjects were investigated. Clinical symptoms were evaluated by means of the Hamilton Depression Rating Scale (HDRS) in case of depression diagnosis and with the Positive and Negative Symptom Scale (PANSS) in case of schizophrenia diagnosis.

Treatment and experimental modulation

Effects of the electroconvulsive treatment course (7–10) and single transcranial magnetic stimulation procedure (11) were evaluated. Overall 55 patients received 6–12 treatment procedures. P300 potential was recorded before and after the treatment course. Seizure duration, systolic and diastolic blood pressure and heart rate during the treatment course (8) were evaluated in 17 patients. Eighteen healthy subjects underwent 10 Hz TMS for twenty minutes and background EEG changes were assessed.

The effect of lactose pill with the accompanying instruction about pill's activating or its sedative properties on background EEG was investigated in 20 healthy subjects (12). Effects of different arousal level (lower / higher) (12–15) and varying attentional demands (unfocused / focused / distracted) (13–18) towards stimulation on background EEG, P50 potential and ASSRs were assessed in 14 schizophrenic patients and 36 healthy subjects.

EEG and EPs

All studies were conducted using conventional EEG recordings. Ag-AgCl electrodes, placed according to the International 10–20 System of Electrode Placement, were used. Impedance was kept below 5 kOhms. The sampling rate in all cases was more than 256 Hz.

Resting EEG was selected as the primary measure of interest in two studies (11–12) and was used to confirm the state of the subject in four other studies (13–14, 16–18). EEG was recorded while subjects were sitting with open eyes. P300 potential was selected to evaluate the effects of electroconvulsive therapy on cognitive processing (7–9). Two tones were presented – one rare tone (1 500 Hz tone) appeared on 20% of the trials, the other one (1 000 Hz tone) appeared on 80% of the trials, and subjects were instructed silently to count rare tones. In response to the rare tones, P300 complex (consisting of N2 and P3 waves) was analyzed. Conventional P50 potential paradigm was selected to evaluate pre-attentitive processing (16–18). Two identical clicks (3 ms, 100 dB) were presented in pairs (50 ms apart) with an inter-pair interval of 10 sec. Conventional ASSR paradigm was selected to evaluate the brain entrainment ability (13–15, 18). White noise clicks were presented in trains of 20 Hz and 40 Hz in a random order.

Background EEG was analyzed using Fast-Fourier Transformation and the power of the delta, theta, alpha, beta and gamma frequency bands was extracted. For the conventional time-voltage analysis, amplitudes and latencies of the P3 peak for P300 potential and the P1 peak for P50 potential were measured. For the time-frequency analysis, data were wavelet-transformed and evoked amplitude, phase-locking index and total intensity measures were extracted. Further, the measures were subjected to non-negative multi-way factorization to extract a single value for each subject describing activity, common for all electrodes and experimental conditions.

RESULTS

It has been shown that the ECT treatment course has no negative impact on P300 cognitive potential – it did not cause amplitude reduction and latency prolongation (7–10). Moreover, the therapeutic ECT outcome as measured by HDRC and PANSS (especially for schizophrenia treatment) was related to normalization of P300 parameters-amplitude increment and latency reduction (7, 9–10). Even more, normalization of P300 parameters was more profound in younger patients' group and was associated with lower changes of the autonomic nervous system activity during the treatment course (8).

It has been shown that even single 10 Hz TMS procedure produces a profound effect on EEG: after the procedure, the generation of slow delta waves in healthy subjects was significantly enhanced (11).

It has been shown that subjects' state (modulated either by instructions given to the subject or by the task) has significant impact on the electrical brain activity. Changes in the arousal level caused changes in background EEG activity (13), transient responses (measured as P1 peak amplitude and phase locking index of gamma burst) (17) and steady-state responses (14–16). During low arousal level conditions, higher P1 amplitudes and more precise gamma bursts and ASSRs, and larger alpha power values were observed. Changes in the attention level affected background EEG activity (17–18), transient responses (measured as phase locking index of gamma burst) (17) and steady-state responses (18): during high attention level conditions with attention focused on task performance, lower and less precise evoked gamma burst and ASSRs, and higher baseline gamma power values were observed.

CONCLUSIONS

During the period of 2005–2012, two EPs, novel for the Lithuanian research practice, were introduced – P50 potential and ASSR, and optimal recording conditions were found. ASSRs received much further attention and currently are used at the Republican Vilnius Psychiatric Hospital with an intention to implement it into a general clinical testing practice. The safety and effectiveness of two non-pharmacologic therapies – ECT and TMS – were evaluated and beneficial effects on cognitive functioning were shown.

The overviewed results are of practical importance as this knowledge enables optimization of registration procedures of evoked potentials, data processing and evaluation, and reveals practical application areas for the methods. Furthermore, the results suggest several practical recommendations. Based on the results, it is recommended to apply P300 potential to evaluate the treatment outcome of the ECT course, especially for schizophrenia patients. Moreover, during the ECT treatment course, when selecting stimulation intensity and duration, it is recommended to evaluate

subjects' age and indexes of the autonomic nervous system activity. It is recommended to apply lower arousal and attention level conditions during EP researches in both healthy and clinical populations and to evaluate the arousal and attention level during experiments. During the evaluation of gamma components of auditory evoked responses, it is not recommended to use distraction tasks.

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NEINVAZINIS SMEGENŲ ELEKTRINIŲ ATSAKŲ ĮVERTINIMAS: NEMEDIKAMENTINIO GYDYMO IR TIRIAMOJO BŪSENOS POVEIKIS

Santrauka

Įvadas. Elektroencefalograma (EEG) ir sukeltiniai potencialai (SP) yra plačiai taikomi psichiatrijoje, todėl svarbu standartizuoti registravimo sąlygas atsižvelgiant į instrukcijas, tiriamojo budrumą, dėmesį, taip pat įvertinti nefarmakologinio gydymo (elektros impulsų terapijos (EIT) ir transkranijinės magnetinės stimuliacijos (TMS)) poveikį EEG ir SP. Šiame darbe apžvelgiami tyrimai, vykdyti minėtomis kryptimis Lietuvoje.

Medžiagos ir metodai. EEG registravimas atliktas pagal standartinį protokolą; registruoti P300, P50 potencialai ir girdimasis nuostovusis atsakas (NA). Ištirti 44 šizofrenija, 25 depresija sergantieji ir 136 sveiki tiriamieji. Vertinti EIT kurso, vienkartinės 10 Hz TMS bei skirtingo budrumo ir dėmesio lygio poveikiai EEG/SP.

Rezultatai. EIT neturėjo neigiamo poveikio P300 potencialui; kartu su klinikiniu pagerėjimu buvo stebimas P300 parametrų normalizavimasis. Nustatytas ryšys su pacientų amžiumi ir autonominės nervų sistemos atsaku gydymo metu. Vienkartinė 10 Hz TMS ženkliai padidino delta diapazono galią. Žemo budrumo lygio metu buvo stebimi didesni ir tikslesni P50, NA bei didesnė alfa diapazono galia. Blaškantis užduoties atlikimo metu buvo stebimi sumažėję gama atsakai ir NA bei padidėjusi gama diapazono galia.

Išvados. EIT gydymo kurso metu rekomenduojama įvertinti P300 potencialo pokyčius ir autonominės nervų sistemos atsakus, kurie susiję su klinikiniu pagerėjimu. Patartina klausos sukeltus atsakus registruoti žemo budrumo ir žemo dėmesio lygio sąlygų metu, kai gaunami didžiausi ir tiksliausi atsakai.

Raktažodžiai: elektroencefalograma, sukeltiniai potencialai, optimalios registravimo sąlygos, elektros impulsų terapija, transkranijinė magnetinė stimuliacija