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The electroencephalographic correlate of cognitive deficiency at the children who had got over a perinatal arterial ischemic stroke

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Abstract

Introduction. It is designated relevance of singling out of the effective electroencephalographic range reflecting cognitive deficiency at the children who had a perinatal ischemic stroke. It is necessary for the subsequent search for early markers of possible cognitive disturbances in later years. The scientific novelty of the study is in attempt of singling out of a neurophysiological correlate of cognitive deficiency at children with rare pathology of the central nervous system with use of the integrated approach including behavioral and equipment-specific methods.

Methods. In the section it is described peculiarities of using electroencephalographic techniques and Bayley-III scales for selection of a neurophysiological correlate of cognitive deficiency in the babyhood and childhood.

Results. The section includes data of statistical processing of a cognitive subscale of the Bailey-III technique and the analysis of the rescaled density of power spectrum of electroencephalographic ranges: beta2 (17–30 Hz) and gamma (30–40 Hz) in projections of prefrontal cortex. The beta2-band showed the greatest ratios with the indicators of the used subscale.

Results and discussion.

It is considered reasons of separation of the children with perinatal arterial ischemic strokes in a group of the high risk of the cognitive disfunction which can develop in course of time. We conclude about a possibility of singling out of beta2-band as the most effective indicator for a neurophysiological correlate of cognitive deficiency at the children who had a perinatal arterial ischemic stroke.

Keywords

babyhood, childhood, perinatal blood-stroke, ischemic stroke, neurophysiological correlates, cognitive deficiency, electroencephalography, Bayley-III scales, beta activity, gamma activity

Highlights

► neurophysiological correlates of cognitive deficiency at children can have some specificity depending on character and time of damage;
► this correlate can make a contribution to further work in search of early markers of cognitive defects at the children having got over a perinatal arterial ischemic stroke and who can progress in later years;
► electroencephalographic beta2 band can be considered as the most effective indicator reflecting cognitive deficiency at the children who had a perinatal arterial ischemic stroke.

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Introduction

The Perinatal Arterial Ischemic Stroke (PAIS) is a local cerebrovascular disturbance caused by thrombosis or embolism during the period between the 20th week of the antenatal life and the 28th day of postnatal period, with the subsequent formation of a local infarction of brain tissue [Fluss, Dinomais & Chabrier, 2019].

Pathology occurrence varies from 1/1600 to 1/5000 according to publications, it is supposed that a part of PAIS cases remain underdiagnosed, in connection with the features of suggestive clinical findings in the neonatal period [Narogan et al., 2019]. The number of children with this pathology increases. It's not so long ago that even the stroke which occurred in infancy was considered as a rarity [Lvova, Kuznetsov, Gusev & Volkhina, 2013].

The perinatal stroke is distinguished as one of the causes of possible forming of the infants' expressed cognitive defects which can worsen over the years [Ilves et al., 2016]. However, using the early markers for identification of high risk group allowing to prove additional therapeutic correction are under discussion at the moment.

The results of the meta-study devoted to the selection of early markers of cognitive defects at the infants revealed that characteristics of background activity of the electroencephalogram (EEG) can be effective for these purposes, however the obtained data were too heterogeneous [Kong et al., 2018].

The variability of indicators is very likely caused by restriction of the possibility of selection of area of interest since the substrates making a contribution to work of cognitive functions, as we know, have not only cortical location [Filley, 2019]. Also, perhaps, features of the studied clinical groups and the nature of cerebral affection exert an impact.

Further work in this direction requires separation of the possible neurophysiological correlate assisting designation of effective EEG-range which will reflect cognitive deficiency at children with PAIS.

Methods

The research was conducted on the basis of the testing laboratory of the brain and neurocognitive development at the Department of psychology in the Ural Federal University named after the first President of Russia B.N. Yeltsin.

Within the case control two groups were formed.

The criteria of inclusion of the participants in the group of control: typically developmental near term infant (37–42 weeks) with the anthropometric measures corresponding to a framework of the physiological norm characterized by absence of significant neurologic and somatic pathologies both at birth and throughout all research period.

The criteria of inclusion of the participants in the experimental group: carried to full time infants with the anthropometric measures at birth which are within the physiological norm, had got over the ischemic stroke (IS) in the mesencephalic artery district during the perinatal life (the brain stroke was confirmed with help of magnetic resonance brain imaging); lack of intracraneal hemorrhages and symmetric periventricular of the ischemic foci. The data of the participants of congenital cardiac event, which was the indication for surgical cardiac interference, as well as the participants of symptomatic epilepsy were rejected.

All the research subjects underwent inspection every other small periods of time. The first stage was carried out in 5 months, then the research procedure was repeated in 10, 14 and 24 months.

These age specific points were selected taking into account:

1. Periodization of the rehabilitation periods of the cerebral thrombosis [Clinical recommendations… , 2013]:

an early recovery period (up to 6 months after the event): point of 5 months;

the late recovery period (up to 2 years after the event): in connection with its duration two points were included – 10 and 14 months;

24 months: it is the point that completes the late recovery period and which is characterized by the end of the most active recovery processes. That fact allows to evaluate fate even at this stage, being guided by the experience of other authors in research of the early diagnostics [Jaillard et al., 2003; Pierrat et al., 2017].

2. "Critical" stages of neurophysiological development of typically developmental children [Marshall, Bar-Haim & Fox, 2002].

68 infants of the control group and 16 infants of the experimental group participated in the research.

The research procedure included the following stages for each participant:

1. Legal representatives of the research subjects carried out giving the voluntary informed consent to participation in the research project.

2. For creation of the greatest homogeneity of the groups under study the form specifying sociodemographic family status was completed by the parents.

3. Conduct of the technique of "Beyley Scales of Infant Development" (Bailey-III).

4. For signal recording of cerebral bioelectrical activity of research subjects the multichannel (128 assignments) electroencephalographic system of the expert class GEODESIC EEG SYSTEM 300 (GES 300) produced by Electrical Geodesic was used. The signal recording was made in the range from 0.1 to 100 Hz, at the rate of digitization of the signal of 1000 Hz and the choice of a vertex (Cz) electrode as a translator.

Technique of "Beyley Scales of Infant Development"

To assess the cognitive sphere of infants of the control and experimental groups, crude points of the cognitive subscale of the Bayley-III scales were used. This technique is the conventional tool used for estimating development of infants aged from 1 up to 42 months [Ballot et al., 2017].

Electroencephalography technique

Registration of the EEG-data was carried out in the darkened screened room, during the procedure the research subjects were in a sitting position on a lap of the parent. For the purpose of accounting on a processing stage of EEG data of behavior of the infant and parent and also control of gaze direction of the child, process video registration, with the subsequent possibility of synchronization with an EEG curve was carried out.

During registration of EEG the quiet, monophonic, repeating video record creating a neutral visual environment, aiding to involvement of examinees in write process that allowed to lower percent of motor artifacts significantly was shown to participants of a research.

For demonstration of video the monitor (1920x1080) located at distance about 60 cm from the infant's eyes was used. As a soundtrack a quiet, melodious music was used.

At the first stage (age coverage of 5 months) of a research of infants, the Hydro Cell Geodesic Sensor Net systems with data recovery were used on oculography sensors, picked up according to the size of the head of the infant. The data traces in later life was carried out using the systems including the oculography ECG sensor located already on an infant's face. This technical feature promotes effective detection of the oculomotor artifacts and also blinking artifacts at childhood.

For primary assessment of the quality of the crude data it was carried out a visual analysis as well as the analysis of resistance value of the electrodes. Posttreatment was made with use of Net Station 5.4 EEG Software. All the EEG traces underwent the procedure of filtering using high-frequency (0.5 Hz) and low-frequency (40 Hz) filters. The EEG sections which are characterized by visual attention of the research subjects to a stimulus material; significant emotional reactions of the child and/or parent, verbal interaction and the expressed by artifact content were divided by absence into short segments lasting 2 seconds. Further automatic and manual analyses of artifacts were carried out. The assignments having poor quality of a signal were interpolated using the built-in program algorithm. Change of an EEG signal of rather general average reviewer behind which it was made by correction of the basic line became the following step of processing.

The received fragments of each research subject underwent fast Fourier transformation (FFT) with use of a Hanning window (overlapping of adjacent windows made 50%).

The power spectrum density was calculated for beta2 17-30 Hz (17.0898–30.0293 Hz) [El-Sayed, Larsson, Persson & Rydelius, 2002] and gamma 30-40 Hz (30.0903–40.0391 Hz) of [Elsabbagh et al., 2009] ranges of interest separated as a projection of prefrontal cortex divided according to the relations to left (12, 18, 19, 20, 23, 24, 27) and to the right (3, 4, 5, 10, 118, 123, 124) hemispheres [Koessler et al., 2009; Luu & Ferree, 2000].

The perimeter-wise electrodes located around the separated zone and electrodes of localization, close to them, were rejected because of a high muscular artifact content at the participants of this age group: 1, 2, 8, 9, 14, 15, 17, 21, 22, 25, 26, 32, 33, 122.

The received data of power spectrum density were subjected to normalization, with use of a formula (10*LOG10 (¼¬é/Hz)).

In the experimental group it was separated the diseased and intact hemispheres that allows to treat separately influence of affect factors on each hemisphere apart, but brings restriction in taking note of physiological lateralization of brain function for the studied indicators.

The total number of the registered the EEG traces made 158 (122 for the control group and 36 for experimental one).

The part of the traces was rejected due to the following reasons:

1. The behavior of the research subject (the moderated/expressed motion activity and/or emotional performance) during registration procedure – 46 traces (29.11%).

2. The technical reasons (failure in performance of a program algorithm, malfunction of the video data-acquisition equipment, errors of carrying out of an experimental procedure) – 3 (1.9%).

3. Emergence of discrepancy to inclusion criteria during the research period (all the data of the participant were rejected from the subsequent analysis) – 12 (7.59%).

As the result, 97 traces (61.39%) were used for the analysis.

The total number of the EEG traces for the control group included into the analysis made 70: the date of 18 infants (11 boys, 5.62 ± 0.3 months) were registered in 5 months, 21 infants (12 boys, 10.71 ± 0.55 months) in 10 months, 18 infants (8 boys, 14.51 ± 0.47 months) in 14 months, 13 infants (6 boys, 25.46 ± 0.86 months) in 24 months.

The total number of the EEG traces for the experimental group included into the analysis made 27: the date of 7 infants (6 boys, 5.44 ± 0.65 months) were registered in 5 months, 8 infants (8 boys, 11.26 ± 0.75 months) in 10 months, 7 infants (6 boys, 15.05 ± 0.44 months) in 14 months, 5 infants (4 boys, 24.82 ± 0.24 months) in 24 months.

The participants of groups were compared according to clinical and anthropometrical data at birth, for an exception of influence of a dismaturity factor (Tab. 1).

Table 1

Clinical and anthropometrical characteristics of research subjects at birth, EEG data of which were included into the analysis

Indicators	The control group; n = 55	The experimental group; n = 12
Gestional age, weeks, avg (SD)	39.5 (± 1.08)	39.57 (± 0.49)
Weight, gr, avg (SD)	3332.56 (± 462.04)	3493 (± 368.5)
Growth, cm, avg (SD)	51.55 (± 2.43)	52.7 (± 1.79)
Head circumference, cm, avg (SD)	34.09 (± 1.31)	34.36 (± 0.97)
Chest circumference, cm, avg (SD)	33.38 (± 1.66)	35.81(± 5.89)
Apgar: at 1 minutes, avg (SD)	7 (± 1)	6 (± 1)

Table 1
Clinical and anthropometrical characteristics of research subjects at birth, EEG data of which were included into the analysis

Apgar: at 5 minutes, avg (SD)	8 (± 1)	7 (± 1)
Sex, N boys (%)	29 (52.73 %)	10 (83.33 %)

Results

Statistical processing was done with the use of the *Statistical Package for the Social Sciences 23.0.*

Intergroup analysis of these Bayley-III and EEG techniques was performed by means of Mann-Whitney non-parametric U-test, due to the small sample sizes and different number of the participants in them.

A comparison of the crude points of the Bayley-III cognitive scale revealed statistically significant differences in only 5 ($p = 0.001$; $U = 12.5$) and in 24 ($p = 0.009$; $U = 5.5$) months.

The comparison of the rescaled density of power spectrum of the EEG in the prefrontal cortex projection revealed statistically significant differences of 5 months in the beta2 band ($p = 0.012$; $U = 22$) in the afflicted hemi-sphere and in beta2 ($p = 0.014$; $U = 23$) in intact hemi-sphere; 24 months: beta2 ($p = 0.013$; $U = 6$) in the afflicted hemisphere. No statistically significant differences were found in the gamma range.

Results and discussion

According to the Kennard principle on the reconstructive processes of the brain, the probability of functional recovery is higher than earlier there was a damage [Kolb, Mychasiuk, Williams & Gibb, 2011]. There is a number of the data of a clarification nature that demonstrate that actively developing brain is more sensitive to the impact of affection processes which are capable to change of its development path [Bennet et al.,2013; de Vries, 1998; Becher, Bell, Keeling, McIntosh & Wyatt, 2004].

In particular, IS which occurred in the perinatal period potentially has an elevated risk of pathological after-effects, in comparison with the cerebral thrombosis at the subsequent childhood [Ganesan et al., 2000].

The range of possible complications of IS is rather wide [Ciccone, Cappella & Borgna-Pignatti, 2011; Kirton & deVeber, 2013; Ramaswamy, Miller, Barkovich, Partridge & Ferriero, 2004; Basu, 2014; Chen et al., 2017]. The sphere of cognitive development is the most difficult in respect of forecasting of outcomes at children with this pathology. At rather similar localization of the centers of ischemia, an effect of IS can have an opposite character [Hajek et al., 2013].

Rather typically developmental children, the children with learning disability or inability to concentrate often show higher level of low-frequency power and lower levels of high-frequency power, respectively [Brito, Fifer, Myers, Elliott & Noble, 2016]. In this connection the beta2 range and the gamma range were selected as some of types of activity of the highest frequency selected in studying of the cognitive sphere [Cannon et al., 2013, Schutte, Kenemans & Schutter, 2017; Park J., Kim, Sohn, Choi & Kim, 2018, Perone & Gartstein, 2019].

The conducted research showed that the beta2 range has the greatest ratio with indicators of the cognitive Bailey-III subscale showing a deficit in 5 and in 24 months at infants with PAIS; that is why it allows to nominate it previously to a role of the effective EEG-range reflecting violations of the cognitive sphere at this pathology.

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