Psychophysiological and Intraoperative AEPs and SEPs Monitoring for Perception, Attention and Cognition

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Abstract. Auditory and somatosensory evoked potentials (AEPs and SEPs) in 14 patients with pathological processes of the brainstem and in 24 healthy subjects were recorded. The procedure of submission of relevant and deviant signals was used for stimulation and registration of evoked potentials. Key evoked potentials changes are as follows. Low amplitude of AEP in patients during a simple rhythmic stimulation generalized was registered. Mainly increasing of the middle latency AEP amplitude during activation of attention was observed. Amplitude increasing of the SEP late components in the central and frontal brain areas normally accompanied by a similar topomaps marked earlier (N30) waves. When pathology increased the amplitude of the field moved to the parietal and occipital cortex.

Keywords: Auditory evoked potentials · Somatosensory evoked potentials · Perception · Selective attention · Corticofugal modulation

1 Introduction

"Excitation process drawn up and sent by braking" – wrote about 100 years ago physiologist Ukhtomskii [12]. In the psychophysiology language such the organization of excitatory processes is the basis of selective attention. Modern views on the possible structural providing of selective attention mechanisms are formed largely due to the results of the registration of fast auditory and somatosensory evoked potentials (EPs). For example, there is information about the effects of efferent nerve centers of the cerebral cortex on the initial (brainstem) signal processing stages. A long time it was thought that the early (fast) waves of the EPs reflect only the transfer for specific sensory information. Now facts about the modulation of endogenous have been received. In other words, fast components have a connection with the processes of sensory perception, selective attention and consciousness [1, 3, 10]. It should be noted that similar results from the registration of EP in the pathology both in neurosurgery and in psychiatry were obtained [4, 7, 8].

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Modern intraoperative monitoring (IOM) of the sensory EPs aims to address three practical problems. Firstly, IOM assists in accurate localization of the pathological process area, secondly, minimizes the random access and (or) transcranial operational corridors for neuronavigation procedures, and, thirdly, it serves for increase the accuracy of registration processes at the physical and molecular levels. From the physiological points of view IOM allows objectively evaluating the function of the nervous system in real time [2].

According to brainstem auditory EPs (BAEPs) in three-dimensional brain space can be calculated wave generators and separate as a result their influence on the pathological lesions. For these goals there are evoked potentials mapping, method of dipole localization (MDL) and method for constructing a three-dimensional Lissajous trajectory (3-DLT).

The aim of this study was to analyze the fast, middle and late components of the auditory and somatosensory evoked potentials in the performance of the psychophysiological tests and evaluation of fast AEP and SEP waves on the results of monitoring neurosurgical operations.

2 Methods

Evoked potentials in the psychophysiological test in 24 healthy subjects (right-handed men aged 20–22 years) and patients with brainstem pathology (before operation, 14 patients aged from 38 to 56 years) in 19 monopolar points were recorded. Data for IOM EPs only for patients on 4 monopolar points were analyzed. At the AEPs recording technique to highlight the relevant background deviant signals having different frequency tone was used. Deviant stimuli for SEPs registration incentives electric current to 40 V above the individual absolute threshold supplied from the electrical stimulator in the projection of the right median nerve were applied. The target (relevant) electrocutaneous signals applied to the area of the right hand were used. Discriminant analysis ($F > 4.0$) and MDL algorithm were applied.

3 Results

Statistical analysis of the AEPs spatiotemporal characteristics compared to healthy subjects is as follows. In a simple rhythmic auditory stimulation significant relief N18 amplitude in parietal ($F = 4.1$ and $F = 6.6$) and a central cortex (sites Cz, $F = 11.0$ and C4, $F = 4.3$), as well as reduction of N40 amplitude in P3 ($F = 4.9$) and C4 ($F = 4.4$) points were registered (Table 1). Relevant stimulation in these cases does not cause significant differences.

Rhythmic auditory stimulation has little effect on the N90 component. N145 wave amplitude increases in left parietal site ($F = 4.6$), and the peak latency (PL) in the vertex ($F = 4.4$). The perception of the target signal is accompanied by a generalized increase of an amplitude and latency N90 (Table 1). At N145 amplitude component in almost all points of registration is recovered, but remains elevated PL in C3 ($F = 5.0$) and C4 ($F = 6.3$).

Table 1. The amplitude-time characteristics (A, uV/T, ms) of the N40 and N90 components AEPs during auditory stimulation with the target signals in patients when compared with the control group

Para-sites meters	N40			N90	
	Control	Pathology	Control	Pathology	
T	P4	40.4 ± 9.6	42.3 ± 9.5	83.8 ± 10.0	98.0 ± 14.0*
A		2.7 ± 0.4	1.7 ± 1.1	2.1 ± 0.7	2.5 ± 1.7
T	P3	42.6 ± 8.2	44.0 ± 8.8	81.8 ± 8.1	95.0 ± 13.6*
A		2.5 ± 0.5	0.9 ± 0.2*	1.5 ± 1.2	2.7 ± 1.1
T	Cz	41.0 ± 7.7	43.6 ± 9.0	84.0 ± 6.3	93.6 ± 11.5*
A		2.1 ± 0.7	1.6 ± 1.0	1.3 ± 0.6	3.4 ± 1.6*
T	F4	43.0 ± 7.1	41.3 ± 4.3	87.4 ± 5.5	95.3 ± 9.2*
A		2.3 ± 1.1	1.3 ± 1.0	1.7 ± 1.0	4.6 ± 1.1*
T	F3	43.0 ± 7.0	41.0 ± 2.4	88.0 ± 3.7	94.3 ± 13.4
A		2.2 ± 0.4	1.9 ± 1.2	1.3 ± 0.3	3.9 ± 1.6**

Notes. F-statistic value by compared to the control: $^{*}F > 4.0$; $^{**}F > 10.0$; in other, the differences are insignificant $F < 4.0$.

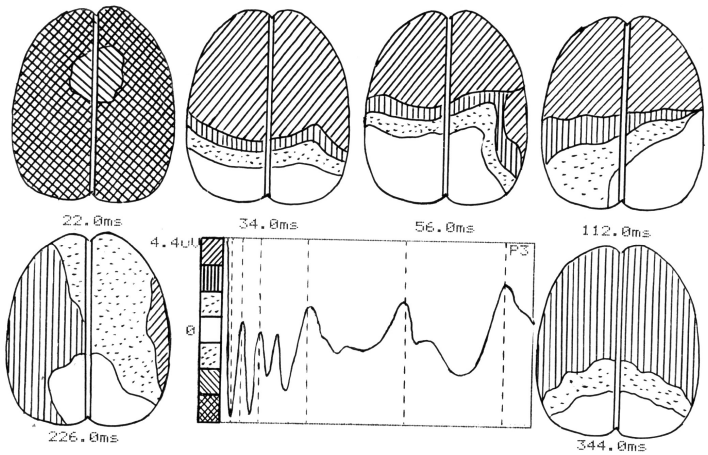

Fig. 1. SEP topomaps in healthy subject in a rhythmic electrical stimulation, ms.

Consider the most typical example of SEP mapping in healthy subjects in both tests (Figs. 1 and 2). With a simple rhythmic electrical stimulation wave P22 of topomap is accompanied by a uniform activation of the entire brain surface (Fig. 1, 22 ms).

In contrast, for the situation with the separation of a useful signal, a less symmetrical pattern is characteristic (Fig. 2, 24 ms). The N30 topomaps in both tests are characterized by the symmetry of excitation of the neocortex with a difference in quantitative values (Fig. 1, 34 ms; Fig. 2, 38 ms). For N60 in almost all parts of the

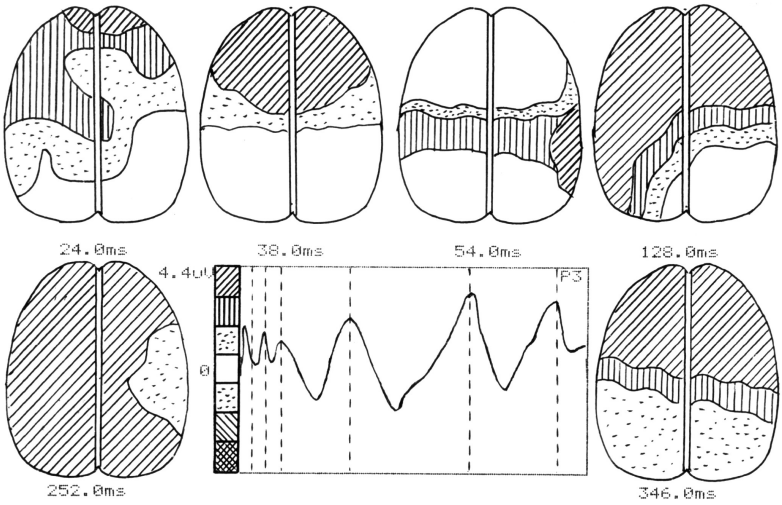

Fig. 2. SEP topomaps in healthy subject in the attention activation, ms.

brain reduction of the amplitude is typical in carrying out the task for attention, as is confirmed by the results of brain mapping (Fig. 1, 56 ms; Fig. 2, 54 ms). The following topomaps are similar to each other (112, 128 ms). In addition, here for the first time there is an asymmetry with a predominance of excitation in the hemisphere, a contralateral stimulated hand.

Marking the wave N200 is characterized by a pronounced map with activation of both hemispheres in the test with the selection of a useful signal (Fig. 2, 252 ms). The topomaps of the component N350 (Fig. 1, 344 ms, Fig. 2, 346 ms) show symmetrical excitations of the field with a difference in absolute values.

The amplitudes N30 and P40 of the SEPs are similar to the control values. At the same time there is a reduction in N30 in the left parietal site ($F = 4.5$). In the test with the allocation of a useful signal, a significant increase in the amplitude of the N30 in both occipital sites (Table 2) and a marked reduction in the frontal regions are recorded as compared to the first test in patients. In addition, PL lengthening in the occipital and parietal areas of the neocortex is observed. In parallel, there is a reduction PL P40 in the right occipital cortex ($F = 4.8$).

In conditions of rhythmic electric stimulation PL N200 increases ($F > 4.0$) only in the parietal cortex. This fact is also characteristic in the attention task, where also an increase in the amplitude of N200 in the occipital sites ($F > 4.0$) (Table 2) is also observed. The temporal characteristics of N350 differ little from the control ones in different tests ($F < 4.0$), however, in the second test there is a significant ($F > 4.0$) relief of the N350 amplitude in the parietal cortex of both hemispheres and in the right frontal cortex.

Table 2. The amplitude-time characteristics (A, uV / T, ms) of the N30 and N200 components SEPs during electrical stimulation with the target signals in patients when compared with the control group

Parameters		N30		N200	
		Control	Pathology	Control	Pathology
T	O2	35.4 ± 4.4	39.5 ± 2.6*	206.4 ± 26.4	232.0 ± 36.5
A		1.0 ± 0.6	3.9 ± 1.6*	2.3 ± 1.5	3.3 ± 2.7 *
T	O1	35.4 ± 3.6	35.0 ± 3.7	206.1 ± 23.7	237.0 ± 31.0*
A		1.5 ± 1.1	3.9 ± 1.8*	1.9 ± 1.4	3.8 ± 1.4*
T	Pz	33.8 ± 3.6	38.5 ± 5.9*	211.8 ± 29.0	243.3 ± 26.7*
A		1.0 ± 0.2	2.0 ± 1.7	1.9 ± 1.1	2.6 ± 1.3
T	F4	34.0 ± 2.9	38.0 ± 6.9	211.5 ± 28.4	231.6 ± 16.5
A		1.0 ± 0.3	1.7 ± 0.5*	2.2 ± 1.6	2.5 ± 0.9*
T	F3	35.2 ± 4.2	37.3 ± 7.3	215.1 ± 29.3	225.6 ± 20.2
A		1.5 ± 0.5	1.3 ± 1.1*	2.2	2.7 ± 0.6

Notes. See Table 1.

4 Discussion

There are quite contradictory information about middle latency AEPs (10–60 ms), their source and localization. These waves can reflect the activity of the first relay neurons of the auditory way or refer to the responses of the primary auditory cortex. There are data that AEPs with PL 12–37 ms from the Hirschlian gyrus of both temporal lobes were recorded. The same components may indicate the inclusion of subcortical delay mechanisms [2–5].

Our data from registering middle latency AEPs (MLAEPs) in the time interval 15–40 ms under the action of the target signals in healthy subjects showed a significant increase in the amplitude of these waves ($F > 4.0$) in the parietal, left temporal and frontal areas of the neocortex. This fact testifies about intensification of consciousness in the form of a mechanism of reverse influence of these parts of the brain cortex to brainstem structures that generate MLAEPs in conditions of activation of attention. Brainstem pathology increases the involvement of parietal cortex in providing feedback afferent mechanisms. This is confirmed by hyperactivation N18 amplitude with predominance in the parietal cortex and the central fields.

The solution of back tasks in order to establish the functional significance of brainstem and subcortical structures in the literature data are controversial. Our IOM data recorded from the midbrain structures show the presence of negative waves in the time sequence following the brainstem auditory EPs. AEPs near-field sequentially recorded at the level of the brain stem and from scalp. These results confirm the importance of brainstem formations in generation MLAEPs. It can be assumed about the localization of the generator of these waves on the brainstem-thalamic level, where cortex is given function of regulator for “volley” of the deep-generated potentials.

If the changes in the components of the MLAEPs in the time interval of 15–35 ms in the control group were reliable, the amplitude-time parameters of N40 and P60 did

not practically differ in both tests. These facts were regarded either from the point of the identity of the mechanisms that ensure the transformation of auditory signals of varying complexity, or the absence of influence of overlying formations on this interval of time on the attention processes. N40 wave in brain pathology is generalized reduced with rhythmic stimulation. However, the amplitude of the next component (P60) under these conditions increases with brain damage mainly in the vertex. In the control group, a noticeable reduction of the N90 AEP can be observed under the conditions of presentation of the target task in all brain areas. In contrast, brainstem pathology, regardless of the nature and location of the lesion, is accompanied by a generalized increase in the N90 amplitude.

The mechanism considered in many respects explains the results obtained by us, where the amplitude of the N90 AEP in normal much higher with simple rhythmic stimulation. Obviously, under such conditions the summation of the allocated signal is more adequate. On the contrary, when the target signal is allocated with brainstem pathology, the amplification of the N90 amplitude is recorded. Thus, for the auditory system there is evidence of a possible selective corticofugal modulation already at the level of the switching brainstem neurons [3, 5].

Researchers of the somatosensory systems [11, 13] are less single-valued to correlate the early SEP components, reflecting the activity of the lemniscus pathways at the level of the brainstem before the switching nuclei of the thalamus, with the target test by subjects performing.

Usually the early somatosensory complex P25–30/N35–40 is considered as the first specific sensory indicator recorded at the thalamo-cortical level. The source of the first of these components (P22 in this work) is considered the switching nuclei of the ventral-basal thalamus complex [2]. Wave N35–40 (N30 in our study) reflects the specific sensory activity resulting from the arrival of afferentation to the primary projection zone along oligosynaptic pathways from the relay thalamus nuclei. The psychophysiological significance of these waves was previously commonly associated with modulation by the physical characteristics of the signal. This is convincingly confirmed by the results of studies with an increase in the intensity of the stimuli. Recently, there have been reports indicating the cognitive role of early waves of SEPs [6, 10, 11]. In particular, it is considered that the components P30 and P40 reflect the activation of information selection mechanisms.

In this research the test with a relevant signal in healthy persons drew attention to the reduction of early SEP waves (P22 and N30) in the frontal and parietal points of the brain, as well as reducing N70 amplitude in frontal sites and in the vertex. It seems to us these facts can be explained from two perspectives. Firstly, by adjusting the peripheral switch to receiving certain information. And, secondly, due to the descending influences from frontal brain to the ascending afferentation. The presence of the descending influences at all levels of the somatosensory systems is currently not in doubt. According to our data brainstem volume processes are accompanied by increased amplitude of the N30 SEP in the occipital departments in the activation of attention. This indicates about the inclusion of adaptive mechanisms with the movement in the occipital cortex.

AEPs and SEPs at the epoch of 150–300 ms are caused both by nonspecific afferent flows from the side of the reticular formation and thalamic nuclei, and from the

mediobasal areas of the limbic cortex, the temporal and frontal lobes, and reflect the decision-making processes [3]. As a rule, the integration center at this time interval moves to the frontal cortex, which plays a key role in managing the processes of attention [1, 9, 13]. In addition, healthy subjects showed similarity in the relationship between excitable areas of the neocortex when labeling SEP waves with 38 ms and 346 ms, suggesting some identity of the processes occurring. Simple rhythmic electric stimulation on these time intervals is also characterized by similar topomaps (34 and 344 ms). These facts can probably be viewed from the position of the mechanisms of the redistribution of attention resources in the CNS with simple stimulation to the early (brainstem) stages of signal processing, and in more complicated ones, to later ones. This situation can also be traced in brainstem pathology where there is an increase in amplitude at these time intervals – N30 and N200 in the occipital cortex of both hemispheres, and N350 – in the parietal cortex.

5 Conclusion

During rhythmic sound stimulation for brainstem pathology generalized reduction and disappearance of MLAEPs and N90 wave of AEP are recorded. Activation of attention is accompanied by an increase in the amplitude of N40 and N90. In both tests PL of the late components is extended. For auditory system there is evidence of a possible selective corticofugal modulation at the level of the switching brainstem neurons.

The increase amplitude N200 and N350 in the central and frontal sites in healthy subjects in both tests is accompanied by similar topomaps with the labeling of early (N30) SEP waves, which is considered from the position of the mechanisms of redistribution of attention resources in the CNS with simple stimulation to the early (brainstem), and at more complex – to later processing. With brainstem pathology the activation of attention strengthens this position, but regions of increased amplitude move to the parietal and mainly to the occipital cortex of both hemispheres.

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