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Age-Related Dynamics of the Parameters of Somatosensory Evoked Potentials in Healthy Children

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Abstract—The purpose of this study was to evaluate the parameters of somatosensory evoked potentials (SSEPs) in healthy children of different age groups ($n = 94$). The amplitudes of the main cortical peaks and the central sensory conduction time (CSCT) from n. medianus and n. tibialis in children aged under 12 months, 1–12 years, and 12–17 years were estimated and compared. No significant cortical peaks were recorded from the tibial nerve in five children younger than 1 year (5 out of 23, 22%). Significant differences in CSCT were observed between the children younger than 1 year and two other groups. The amplitudes did not significantly differ between the groups. Thus, SSEPs may be used for the evaluation of somatosensory pathways in children aged one month to 17 years. CSCT differs significantly between children younger than 1 year and other age groups. Age-related reduction in CSCT and elevation of the cortical peak amplitudes may reflect the myelination of somatosensory pathways and the improvement in nervous system integration.

Keywords: somatosensory evoked potentials, normal values, children
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Objective investigation of the somatosensory system in children is characterized by high complexity due to insufficient contact with a patient and, sometimes, his or her inability to objectively assess and express their perceptions. Under these conditions, an important role is played by the study of somatosensory evoked potentials (SSEPs) [1]. SSEPs reflect the functioning of the somatosensory system and can be recorded even in preterm newborns. Nevertheless, in infants, the absence or marked asymmetry of the SSEP components may reflect a physiological delay in the myelination of somatosensory pathways rather than a pathological situation.

Among the newborns with no SSEP recorded, repeated examination two or three months later revealed them in 80% [2]. The development of the somatosensory system and a relevant change in the SSEP parameters in full-term infants are considered to occur most rapidly in the first three weeks of life [1]. In newborns, generation of spontaneous activity of the somatosensory cortex mainly occurs due to an activation of sensory systems on the periphery [3], i.e., in response to a stimulus.

At present, somatosensory evoked potentials are most often used in children in the framework of intraoperative monitoring where their high information value has been confirmed by recently conducted large-scale studies [4, 5]. SSEP are also used with a prognostic purpose in neonatology, in particular, for predicting unfavorable outcomes in preterm neonates with an extremely low body mass [6, 7].

As distinct from the well-studied and established normative SSEP parameter values in adults, these data for children differ in various centers [8]. Age-related shortening of the SSEP cortical peak latencies is indicated in the literature [9], but there is no general consensus on the dynamics of the amplitude parameters of short-latency evoked potentials in children [10]. In some works, no numerical data that allow comparison with the values obtained are provided [11]. A higher SSEP cortical peak amplitude is reported in healthy children compared to healthy adults [12].

International recommendations on clinical neurophysiology propose that every laboratory determine its group of reference values; data comparison between laboratories is only possible under the conditions of exact repetition of the study procedure, including the SSEP current strength, stimulation frequency, and the arrangement of recording electrodes [1, 8].

The aim of this study was to look into somatosensory evoked potentials in healthy children whose ages varied between 1 month and 17 years.

METHODS

The study of somatosensory evoked potentials was conducted in healthy children at the Pediatric

Table 1. Central sensory conduction time and the cortical peak amplitude in the examined group of children

Age	Infants under 12 months		Children aged 1–12 years		Children aged 12–17 years	
parameter	on the right	on the left	on the right	on the left	on the right	on the left
*N*13–*N*20 interval, ms	12.15 ± 2.96	12.87 ± 3.45	6.35 ± 1.98*	6.63 ± 1.19*	5.75 ± 1.71*	6.17 ± 1.68*
*N*22–*P*37 interval, ms	26.42 ± 3.59	27.29 ± 3.09	21.97 ± 2.94	21.88 ± 1.96	16.36 ± 2.33*	15.61 ± 2.24*
Amplitude of *P*37, μV	2.12 ± 1.63	2.34 ± 1.51	3.79 ± 2.52	4.05 ± 2.62	6.42 ± 1.59	6.16 ± 2.11
Amplitude of *N*20, μV	3.25 ± 2.09	3.51 ± 1.75	4.14 ± 2.46	5.42 ± 2.77	5.15 ± 2.65	5.64 ± 2.25

* Differences from the 1–12 months group are significant, $p < 0.05$.

Research Clinical Center of Infectious Diseases of the Russian Federal Biomedical Agency. A total of 94 neurologically and somatically healthy children (57 boys and 37 girls) underwent screening examination. The age of the subjects varied between 1 month and 17 years. The group was divided into three age-related subgroups: infants under 12 months ($n = 23$), children aged from 12 months to 12 years ($n = 43$), and children aged from 12 to 17 years ($n = 28$).

All the children were subjected to thorough neurological examination, neurosonography or neuroimaging methods of examination, and electroencephalography. The children's data were included in the study if they had no deviations from the normal values.

SSEPs were studied according to the standard method [13] upon percutaneous electrical stimulation of the median nerve at the level of the wrist and the tibial nerve bilaterally. The intensity of stimulation was adjusted by hand until the movements of the thumb or toe appeared, constituting 7 mA on average (from 5 to 10 mA), with a frequency of stimulation of 2 Hz in all the studies.

In order to study SSEPs from n. tibialis, four recording channels were used (the first channel with an active electrode in the popliteal fossa 4 to 6 cm above the bend of knee; the reference electrode above the medial epicondyle of femur; the second channel, above the spinous process of the first lumbar vertebra with a reference electrode on the sacrum; the third channel, with an active electrode in the projection of CVII and a reference electrode at the *FPz* point of the international 10–20 scheme; the fourth channel, with an active electrode at *C*3–*C*4 and a reference electrode on *FPz*).

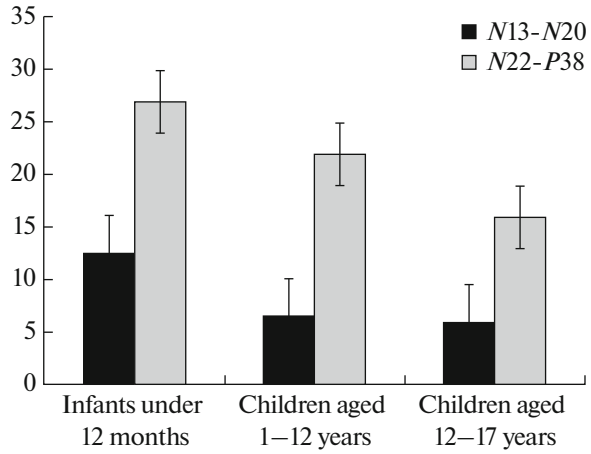

Fig. 1. Comparison between the central sensory conduction times in the age groups.

SSEPs from n. medianus were studied according to the three-channel scheme, with the first channel with an active electrode at Erb's point and a reference electrode at the contralateral Erb's point; the second channel with an active electrode above the spinous process of *C*5 and a reference electrode on *Fpz*; and the third channel with an active electrode in the region 2 cm posterior to *C*3 and *C*4 of the 10–20 scheme and a reference electrode on *Fpz*.

Impedance was measured before each series of investigations and did not exceed 10 kΩ in each case. Averaging was carried out for 1000–1500 stimuli.

For analysis, we considered the following potentials: *N*13 (cervical enlargement potential), *N*20 (potential of the neurons of the arm cortical projection zones), the interpeak *N*13–*N*20 interval showing the central sensory conduction time (CSCT), the spinal cord lumbar enlargement potential *N*22, and the cortical potential *P*37. The amplitudes of cortical potentials *N*22 and *P*37 were assessed. A Neiro-MVP device (Neirosoft, Russia) was used for neurophysiological studies.

All the patients or their lawful representatives gave a written informed consent to take part in the investigation whose aims and objectives were explained to them.

Statistical analysis was carried out using the Statistica package for Windows. Student's *t* test was used for normally distributed parameters. The $p < 0.05$ value was considered to be statistically significant. The data obtained for the age-related subgroups were compared.

RESULTS

Cortical peaks upon stimulation of n. medianus were recorded in all the children who took part in the study. Cortical peaks were recorded from n. tibialis in

89 children (95%). No significant cortical peaks were revealed in five infants in the 1–12 months group (5 out of 23 infants, 22% of the subgroup).

The central sensory conduction time and the bilateral cortical peak amplitude parameters in children from the age groups studied are shown in the table 1.

As seen from the tabulated data, the age-related reduction in the central sensory conduction time and the elevation of the amplitude of cortical responses were noted in children. Comparison between the central sensory conduction time parameters in the age groups is shown in the Fig. 1.

No significant differences in the SSEP parameters were revealed between children for the lateral profile, neither were significant gender differences recorded.

DISCUSSION

Considerable scatter of latencies revealed in the subgroups of infants reflects incomplete myelination of somatosensory pathways typical of children in the first year of life [1]. When the parameters of children from different age groups were compared, a steady reduction in the SSEP peak latencies and a gradual elevation of their amplitudes were observed.

Under pathological conditions (in children with viral encephalitis), the CSCT parameter also steadily decreased with age (7.6 ± 2.5 ms in children aged 2–6 years; 6.9 ± 1.6 ms in children aged 7–12 years; and 6.0 ± 1.9 ms in children aged 12–17 years) [13]. The cortical peak amplitude in these children was 1.9 ± 1.2 μV in the two- to six-year-olds; 1.5 ± 0.9 μV, in the 7- to 12-year-olds; and 0.9 ± 0.64 μV, in 12- to 17-year-old children [13].

The normative SSEP parameters in children, especially in the first year of life, substantially differ in various sources. The result is age-related and depends on the changes occurring in the first months of life [7]. In healthy infants in the 1–12 months group the following data are reported: the average latency of *N*13, 10.1 ± 0.5 ms and CSCT, 28.2 ± 4.5 ms [14]; the average latency of *N*20, 30.0 ± 6.8 ms and CSCT, 19.8 ± 6.5 ms [1]. In children aged 1–15 years (inclusion in the group of children with such a wide scatter of age without dividing into subgroups seems questionable), the average latency of *N*13 constitutes 12.32–12.64 ms; the *N*13-*N*20 interval (CSCT), 4.9–4.98 ms; and the cortical peak amplitudes, 1.12–1.55 μV [15]. In children aged 5–12 years, the average cortical peak amplitude 1.46 ± 0.62 μV [12], 2.05 ± 1.29 μV and the average CSCT 8.32 ± 1.13 ms [16] are reported.

The SSEP parameters on stimulation of the femoral nerve in children, especially in the first year of life, are characterized by more marked scatter and instability of the main peaks than the median nerve [1]. The absence of cortical peaks in 22% of cases on stimulation of the tibial nerve of children under 12 months of life coincides with the literature data and may reflect normal heterochronia of maturation of the nervous system structures.

Thus, the CSCT parameter in the group of healthy children examined by us decreased with age. The SSEP were of significant and recurrent character in 95% of the group enabling us to objectively evaluate the state of the CNS even in infants younger than 12 months. The *P*37 cortical peaks were not acquired in 22% of cases from the 1–12 months subgroup, but *N*20 peaks were recorded in all the infants; thus, the SSEP technique has no significant age-related limitations in contrast to diagnostic transcranial magnetic stimulation whose performance makes the acquisition of significant cortical responses in infants younger than two years extremely difficult or requires the application of special techniques [17, 18].

The thickness of the somatosensory cortex in children from different age groups is known to differ significantly; it has also been shown that in children aged 8–12 years, predominantly left-hemispheric dominance is noted in the somatosensory cortex area 1 and the frontal cortex speech motor area 45; in the visual cortex projection associative area 19, predominantly right-hemispheric dominance [19]. In a number of works, interhemispheric asymmetry of the SSEP parameters was revealed in children from different age groups described for patients over eight years [1, 12]. Under the conditions of our study, we did not succeed in revealing significant differences in the parameters of latency and the SSEP cortical peak amplitude between the sides.

It may be suggested that the steady reduction in the central sensory conduction time and the elevation of amplitude in the study group of children reflects the myelination of somatosensory pathways and the improvement in nervous system integration. This can be manifested electrophysiologically and recorded by means of somatosensory evoked potentials.

CONCLUSIONS

(1) Somatosensory evoked potentials can be used for the objective assessment of the state of somatosensory pathways in children aged one month to 17 years.

(2) There are significant differences in the central sensory conduction time values between the SSEP parameters in children younger than 12 months and 1–12- and 12- to 17-year-old children.

(3) The age-related reduction in the central sensory conduction time and the cortical peak amplitude increase may reflect the myelination of somatosensory pathways and the improvement in nervous system integration.

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