Age-Related Brain Activity in Patients after Traumatic Brain Injury and Cerebral Infarction

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Abstract—Stroke and traumatic brain injury are disabling diseases that determine the medical and social relevance of the rehabilitation. Age is one of the important risk factors for the development and clinical course of strokes. The aim of this study was to research the features of the restoration of cognitive function and brain activity in patients who underwent ischemic stroke and traumatic brain injury. 72 individuals were examined (43 males and 29 females with a mean age of 37.51 ± 42.97 years). Brain DC potentials were recorded in all patients before and after rehabilitation treatment. Age factor plays an important role in the process of cerebral recovery after brain injury. In patients aged 40 and younger, rehabilitation was connected with increasing activity in the right hemisphere. In patients older than 40 years, the restoration of cerebral function was connected with the activity of the left hemisphere of the brain.

Key words: stroke, traumatic brain injury, brain DC potentials, age, neuroplasticity, autonomic nervous system
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INTRODUCTION

Stroke and traumatic brain injury (TBI) are disabling diseases that determine the medical and social relevance of the rehabilitation [11, 18]. Age is one of the important risk factors for the development and clinical course of stroke [11]. This results from the range of functional activity and the narrowing compensation abilities of cardiovascular, nervous, and immune systems, as well as limiting units causing predisposition to the development of cerebrovascular diseases (in particular, strokes) [26]. To date, the age-related peculiarities of pathogenic mechanisms of the development and clinical course of stroke are established, which results in the need to develop effective rehabilitation measures with age-related peculiarities of metabolic, hemodynamic, and morphometric brain reorganization taking into account patients with stroke [6, 12, 26].

Physiological base for functional recovery after vascular or traumatic cerebral accident is neuroplasticity [2] and neurogenesis [17]. The recovery strongly depends on a number of factors, such as lesion size, localization and lateralization, patient’s initial somatic state and age [3]. The effect of the last factor remains unclear.

Neuroplasticity tends to decrease with age, however, this does not mean that age is the determining factor for recovery. There is no agreement among researchers on the effect of age on motor functions; some believe that middle age is one of the major unfavorable factors [20, 21], while others deny its significance [19]. Most scientists agree that, with similar initial severity of motor disorders and focal lesions that are similar in size and localization, the recovery of paretic limb movements does not depend on age [3, 4, 10]. At the same time, in middle-aged and old patients the recovery of walking and rate of self-service are significantly slower and worse [1, 2, 24]. A number of factors have been revealed that negatively affect the restoration of complex motor functions, including old age, intellectual disabilities, a decrease in mental activity, somatic aggravation, etc.

A series of reports submitted by Stroke Outcomes Research Canada Working Group showed that although elderly patients have higher level of intrahospital lethality [29], the use of specialized care for stroke is of equal importance in all age groups [29].

To understand the influence of age on the clinical course of cerebrovascular diseases, S.M. Kuznetsova et al. (2008) studied the state of cerebral hemodynamics and metabolism in middle-aged and old patients with atherothrombotic ischemic stroke and revealed age-related peculiarities of mechanisms of post-stroke reorganization [7]. The authors demonstrated that in patients with stroke changes in interconnections between metabolism and hemodynamics occur with age, which is probably one of the mechanisms that determine the age-related peculiarities of their reorganization during the recovery period. With this, during the recovery period after a stroke, middle-aged...
Differences between groups with respect to the deviation from the mean value in the left temporal lead ($T_5^*$) before treatment, $M \pm m$

<table>
<thead>
<tr>
<th>First group (healthy)</th>
<th>Second group (stroke)</th>
<th>Third group (TBI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-3.14 \pm 0.93^{* \ast \ast}$</td>
<td>$0.22 \pm 0.75^*$</td>
<td>$0.36 \pm 1.28^{\ast \ast}$</td>
</tr>
</tbody>
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Note: $^* \ast \ast$ indicate significant differences from the first group (ANOVA, $p \leq 0.05$).

RESULTS AND DISCUSSION

At the first stage, the difference between groups was estimated using mentioned indices in normal and pathological states (table). According to the brain DC potentials, healthy patients differ significantly from those with brain pathology in the deviation from the mean value in the left temporal lead ($T_5^*$), i.e., in local brain DC potentials in the left temporal lead. It has been revealed that healthy patients have a deviation from the mean value in the left temporal lead ($T_5^*$) that is significantly lower than in patients with TBI (ANOVA, $F = 4.83; p = 0.036$) and the acute impairment of cerebral blood flow (AICBF) (ANOVA, $F = 6.11; p = 0.017$). This increase in local brain DC potentials may be connected with the increase in the portion of anaerobic oxidation in lesioned hemisphere, since brain DC potentials increase with the accumulation of acidic products in brain tissue [13].

At the second stage, the dynamics of the recovery of energy brain activity with respect to age was estimated. In patients with AICBF, after remedial actions were taken, the dependence of recovery on age was demonstrated using indices of brain DC potentials. By comparing two age groups, the significant differences have been found in remainders of brain DC potentials before and after treatment in the right temporal lead ($T_d$) in different age groups in response to rehabilitation measures. This remainder was opposite in sign, which indicated the multidirectional change in neuron activity in the right hemisphere. According to the Kruskal–Wallis one-way analysis of variance, the differences are significant between different age groups as follows: $KW = 7.4; p = 0.006$.

A similar pattern is observed for interhemispheric differences between brain DC potentials in temporal leads ($T_d-T_S$). In patients aged 31–40 years, $T_d-T_S$ was $1.82 \pm 1.34$ (before treatment), $8.29 \pm 7.14$ (after treatment), and in patients 41–50 years of age the pattern was very different $1.49 \pm 1.21$ (before treatment), $-9.74 \pm 4.55$ (after treatment), ANOVA, $F = 5.32; p = 0.03$.

In response to rehabilitation measures in brain DC potentials in the right temporal lead ($T_d$), patients younger than 40 have an increase in indices from $7.07 \pm 1.84$ mV before treatment to $18.59 \pm 3.32$ mV after...
treatment. In patients aged older than 40, the opposite pattern was observed and indices of brain DC potentials decreased from 9.09 ± 1.93 mV before treatment to 6.40 ± 2.89 mV after treatment. The differences in dynamics are also significant between different age groups according to Kruskal–Wallis one-way analysis of variance as follows: $KW = 6.7; p = 0.01$.

Thus, in both age groups, after a cerebral accident but before treatment, the right hemisphere was more active. After treatment in patients 31–40 years of age, this pattern was conserved and, in patients aged 41–50, the left hemisphere became more active, which might indicate a change in the strategy of cerebral rehabilitation with age. As can be seen from the presented plots, there is a positive age of 40 years for indices of brain DC potentials, before and after which responses of brain to treatment are diametrically opposite (figure).

Having carried out the investigation we have obtained two main results. First, in cerebral accident (TBI, AICBF) in the pool of the left middle cerebral artery there is a local increase in indices of brain DC potentials in the left temporal area. Second, patients who underwent TBI and AICBF have different recovery profiles according to their age. In patients aged younger than 40, in response to medical rehabilitation measures in the frontal and right temporal leads, interhemispheric asymmetry increased (with right hemisphere becoming active) and, in patients after 40 years, it decreased. Special attention should be paid to the latter result.

Age-related recovery after a cerebral accident is an old, important, and highly debated problem. According to E.V. Shmidt, “after age 40, the frequency of stroke increases threefold with every decade”; the death rate also increases with age, i.e., there are 530.3 cases per 100,000 among people over the age of 60 [16]. This is an incontestable fact that indicates that the response of organs (including brain) to ischemic lesion changes with age.

To date, there is no agreement on the effect of age on the recovery of impaired functions. Some researchers believe that, in middle-aged and old patients, the recovery of impaired functions is worse than in young patients, since in people of old age, there is a loss of multiplicity of neurons in the cortex, a decrease in the activity of cortex cells and motor activity, and lesions of other systems and organs (cardiovascular and locomotor diseases, diabetes mellitus, etc.). According to other data, there are no significant differences in the degree and rate of recovery between patients of old age and middle-aged and young individuals without apparent associated illnesses [16]. The latter has also been confirmed by the strategies of treating and rehabilitating patients of old age abroad [29].

As mentioned above, neurogenesis and neuroplasticity underlie recovery after stroke and TBI. In turn, the potency of the processes depends on many factors, including the brain’s blood supply, the activity of biochemical processes, the autonomic tone of the nervous system, etc.

The age-related peculiarities of mechanisms of post-stroke reorganization in patients of middle and old age who suffered from atherothrombotic ischemic stroke have been shown in the literature. In middle-aged patients, a common feature is a decrease in the rate indices of cerebral hemodynamics in vessels of both lesioned and intact carotid pool compared to middle-aged people without cerebrovascular pathology. In patients of old age, the decrease in these indices is less pronounced [7].

According to our results, after age 40, there is a decrease in the indices of brain DC potentials in the right hemisphere in response to the rehabilitation program, which is evidence of a decrease in the activity of regions involved and can correlate with some decrease in their blood flow. The decrease in the activity of individual regions of the brain with aging has been shown in investigations carried out previously [9].

From our point of view, a special role in processes of neurorehabilitation can be played by the autonomic tone of the nervous system, which is one of the regulators of brain blood flow, vessel tone, and heart function. One of the indices of the state of the autonomic nervous system is heart-rate variability. With aging, the reflex effects on cardiovascular systems are weakened and the disintegration of different levels of autonomous regulation of heart function is observed [23, 25]. Cardiology clinical data demonstrate a weakening of
autonomic effects on the cardiovascular system during aging [8], with weakening of parasympathetic effects on heart occurring more quickly. As a result, in people of old age, compared to the common decrease in autonomous tone, sympathetic regulation becomes prevalent [5, 22, 27].

In studying brain physiology, the connection between interhemispheric asymmetry and the autonomic nervous system state has been shown. The activation of the left hemisphere leads to the enhancement of parasympathothonia and that of right one results in sympathicotonia [14, 15].

According to our results, in people of old age, the activity in the right hemisphere decreases in response to rehabilitation, i.e., the relative activation of the left hemisphere occurs with parasympathothonia being prevalent.

One should bear in mind that, in the group studied, patients had structural lesions of the left hemisphere that result in the fact that, even upon the activation of this hemisphere, according to the data of neurophysiological techniques, the real response of functional systems (including autonomic one) can change slightly. At the same time, the activation of the parasympathetic nervous system could determine the less favorable prognosis of recovery measures.

There is little information concerning the effect of hemispheric stroke on the autonomic tone of the nervous system in the literature [28], which indicates the need for further investigations.

CONCLUSIONS

In the acute impairment of cerebral blood flow and traumatic brain injury, the violation of the integrity of neurons and their connections occurs, which affects the brain’s metabolism due to cognitive processes and brain DC potentials. The patient’s age plays an important role in recovery processes. After age 40, recovery develops in the opposite direction with respect to interhemispheric characteristics compared to younger patients. Recovery after cerebral accident can be determined largely by the autonomic tone of the nervous system.

REFERENCES


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