NEUROPHYSIOLOGICAL PREDICTORS OF ACUTE HEMORRHAGIC STROKE

Sadullayeva Kunduz Abdullo kizi
Bukhara State Medical University
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Abstract Stroke is the most important medical and social problem, due to its high proportion in morbidity, subsequent disability and mortality among patients of working age. The purpose of the study. Prediction of the course of the acute period of hemorrhagic parenchymal stroke (supratentorial hemispheric hematomas) based on neuroimaging data (localization, lateralization, hematoma volume) and neurophysiological data.

Keywords: hemorrhagic stroke, NHISS, cluster analysis, neural network

Materials and methods. 102 patients suffering from hemorrhagic stroke were examined. The assessment of the level of consciousness, focal neurological syndromology, neuroimaging data, neurophysiological data (EEG, heart rate variability, auditory potential associated with the event) was carried out. The condition of patients at admission and in dynamics was assessed on the basis of the Glasgow Coma Scale, the extended Glasgow Coma Scale and NIHSS Results. Based on the results of cluster analysis and expert assessments, two groups of patients were identified – with a relatively favorable and unfavorable course of the acute period of hemorrhagic stroke. Differences in neurophysiological parameters in the groups were established: an increase in the power of theta oscillations and a decrease in the frequency of theta oscillations of the electroencephalogram, a decrease in the amplitude of the N2P2 component of the cognitive evoked potential P300, an increase in heart rate during an unfavorable course. An artificial neural network has been created to predict the course of an acute period of hemorrhagic stroke upon admission.

Резюме Инсульт является важнейшей медико-социальной проблемой, что обусловлено его высокой долей при заболеваемости, последующей инвалидности и смертности среди пациентов трудоспособного возраста. Цель исследования. Прогнозирование течения острого периода геморрагического паренхиматозного инсульта (супратенториальных полушарных гематом) на основе данных нейровизуализации (локализация, латерализация, объём гематомы) и нейрофизиологических данных.

Ключевые слова: геморрагический инсульт, NHISS, кластерный анализ, нейронная сеть

Материалы и методы. Обследовано 102 пациентов, страдающих геморрагическим инсультом. Проводилась оценка уровня сознания, очаговой неврологической синдромологии, данных нейровизуализации, нейрофизиологических данных (ЭЭГ, вариабельность сердечного ритма, слуховой потенциал, связанный с событием). Состояние больных при поступлении и в динамике оценивалось на основании шкалы комы Глазго, расширенной шкалы комы Глазго и NIHSS Результаты. На основе результатов кластерного анализа и экспертных оценок выделено две группы пациентов – с относительно благоприятным и неблагоприятным течением острого периода геморрагического инсульта. Установлены различия нейрофизиологических показателей в группах: увеличение мощности тета-колебаний и уменьшение частоты тета-колебаний электроэнцефалограммы, снижение амплитуды N2P2-компонента когнитивного вызванного потенциала P300, увеличение частоты сердечных сокращений при неблагоприятном течении. Создана искусственная нейронная сеть, позволяющая прогнозировать течение острого периода геморрагического инсульта при поступлении.

According to statistical studies by the American Heart Association, according to NHANES, 7.2 million Yankees over the age of 20 had a violation of cerebral circulation during the 2011-2014 stage. Every year, approximately 795,000 people experience a fresh or recurrent heart attack, within 610,000 of them – an initial heart attack, and 185,000 – repeated cases. Of all strokes, 87% are ischemic strokes, 10% are hemorrhagic strokes and 3% are subarachnoid hemorrhages [1, 2, 3]. There is no clear municipal stroke statistics in our country. Only the total number of cerebrovascular diseases is counted. Forecasting the course of the acute period of hemorrhagic infarction forms 1 of the timely tasks of angioeducology, in fact, which is justified by the extreme stress of compensatory and adaptive devices of the body in the acute stage of cerebral hemorrhage, greater mortality in this stage, and also by the fact that the direction of the acute period of hemorrhagic infarction largely determines long-term monitoring both in the project of public rehabilitation and active rehabilitation (disability), for example, in the project properties of the life of patients [4, 5]. According to the literature [6], the main point determining the direction of the acute period is considered to be the localization and volume of hemorrhage and, in many respects, the degree of focal neurological symptoms consistent with the paradoxes.

The aim of the study is to predict the course of the acute period of hemorrhagic parenchymal infarction (supratentorial hemispheric hematomas) on the basis of neuroimaging data (localization, lateralization, hematoma volume) and neurophysiological data based on machine learning technology. Materials and methods the study included 86 patients (46 men, 40 women) with an established diagnosis of hemorrhagic infarction, the average age was 67.65 years. The diagnosis was established on the basis of clinical examination data, neuroimaging data (X-ray computed tomography) and anamnesis data. The diagnosis of hemorrhagic stroke was determined on the basis of neuroimaging data, medical syndrome-logy and anamnesis (features of the onset and course of the disease), clinical and laboratory data. The qualities of inclusion in the study included: – non-traumatic hemispheric hematoma of supratentorial localization confirmed by computed tomography, verified on the day of admission; – the absence of painful indications for surgical healing. The qualities of exclusion were: – subtentorial localization of hematomas (cerebellar, stem); – subarachnoid hemorrhages, aneurysmal hemorrhages; – ventricular hemorrhages. The condition of patients at admission and in dynamics was assessed on the basis of the Glasgow Coma Scale (SCG), the extended Glasgow coma scale and NIHSS [7]. The assessment of the meaning of consciousness according to the SHG was carried out in the usual way in points from 3 to 15 based on the eye opening reaction, motor reaction, and speech reaction. The oppression of neurological symptoms in the acute period of hemorrhagic infarction was assessed using the NHISS scale with an assessment of the meaning of consciousness, focal neurological symptoms. To assess the dynamics of the condition of patients with hemorrhagic infarction, the properties of NIHSS

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were evaluated, as well as the Glasgow coma scales on the 1st (day of admission), 3rd and 21st days. Initially, the isolation of a group of patients with a negative unpleasant period was based on the death of the sick due to edema-swelling of the brain and central asphyxia, beyond dependence on the meaning of the initial neurological defect. Among the surviving patients, the cluster analysis method additionally focused on subgroups with different dynamics of neurological deficiency. After that, these subgroups were evaluated by the level of dynamics of focal neurological status and the level of disorders of consciousness, the final groups of patients were formed: group 1 – patients with a favorable course (regression of neurological deficit), group 2 – patients with an unfavorable course (death of patients in the period from 1st to 28th day, stable pronounced neurological deficit or its build-up) The heart rate (HR), mean square deviation, coefficient of variation, voltage index of regulatory systems were evaluated. The power analysis of the spectral components of the dynamic series of cardiointervals was performed with the determination of the power of slow waves of the 1st order (LF), slow waves of the 2nd order (VLF) [10, 11] Statistical differences between the groups were estimated using nonparametric statistics using the Mann- Whitney criterion U (Z), the description of the data assumed the allocation of the median (Me), lower (LQ) and upper quartile (UQ). The creation, training and testing of artificial neural networks was created using the Statistica 10.0 Ru program [12, 13]. As a control group (to assess the validity of the applied neurophysiological indicators), a group of patients (28 people) with dorsopathy of the cervical spine (moderate musculotonic syndrome), beyond the acute stage without neurological disorders, indications of episodes of impaired cerebral circulation in the anamnesis and symptoms of compression and hemodynamically important stenoses of the main vessels of the cervix were examined. according to ultrasound Dopplerography. Results Based on cluster analysis and expert assessments, appropriate groups of patients with hemorrhagic infarction were given – group 1 (favorable direction, 37 patients) and group 2 (unfavorable direction, 38 patients) (Table 1). Table 2 shows the comparative intergroup properties between patients with hemorrhagic infarction. The groups with a suitable and negative course differed statistically significantly according to the results

Table 1 Clinical characteristics of subgroups, Me (LQ; UQ)

Indicator	Group 1 (favorable current)	Group 2 (adverse course)	Statistical differences	
			U	p
NIHSS, 1st day	6 (4; 8)	18 (12; 27)	–6,2	0,001
NIHSS, 3-st day	4 (3; 6)	17 (11; 27)	–5,6	0,001
NIHSS, 28-st day	4 (2; 6)	17 (13; 26)	–5,7	0,001
ШКГ, 1st day	15 (13; 15)	10 (3; 13)	5,2	0,001
ШКГ, 3-st day	15 (13; 15)	10 (3; 13)	3,6	0,001
ШКГ, 28-st day	15 (14; 15)	12 (3; 13)	3,6	0,001

Note. When analyzing the indicators in group 2 on the 3rd and 21st days, deceased patients were excluded.

Latencies in the leads Pz, Cz and Fz; amplitudes P2N2 – in the leads Pz and Cz, and also according to heart rate variability, such as SDNN, VLF and LF. The creation, study and testing of artificial neural networks were brought to life with the support of the Statistica 10.0 Ru software package. The development of machine learning hoped to create 2 groups of neural networks: the 1st group - to conclude a forecasting task based only on the characteristics of neuroimaging, the 2nd group – to conclude a forecasting task based on an ensemble of both neurophysiological, for example, and neuroimaging characteristics. Thus, an assessment of the role of a group of neurophysiological characteristics in predictive assessment was expected. To improve the properties of the model, we proposed to expand the number of predictors due to the characteristics (neurophysiological correlates) of the value of the interaction of stem modulating structures (power and frequency of theta oscillations in frontal leads), devices for identifying the presented auditory catalyst (amplitude and latency of the N2 component of the endogenous evoked potential P300), as well as vegetative regulation devices (variability indicators heart rate). The provided neural network provided a multi-layered perceptron with 17 input neurons, 9 neurons of the perineal layer and 2 output neurons. The performance of the student selection was 100%, control – 85%, test 95% (MLP 22-9-2; 100:85:95). Table 3 demonstrates the classification properties of the artificial neural network provided. Table 4 shows the predictors used to conclude the prediction problem. The operational data curve for the artificial neural network provided is shown in Figure 1. Consideration Characteristics reflecting the relationship of cortical-subcortical structures and regulation of the active state of the brain (frontal structures – characteristics of the frequency and power of theta oscillations), neurophysiological correlates of identification of the presented catalyst (indicators of P2N2 and latency N2), as well as properties of central devices of vegetative regulation of work were integrated into the study. As follows in the footsteps of the presented results, the heterogeneity of the group of patients with a painful level of consciousness is naturally associated with the volume of a hematoma, which is actually guided by a specific loss of brain tissue, for example, perifocal edema and secondary neurodynamic disorders. The results of the cluster analysis showed the identification of groups with a relatively suitable and negative course of hemorrhagic infarction. The correlate of the negative dynamics turned out to be reduced bioelectrogenesis in the associative zones of the cortex during identification of the catalyst and acceptance of the conclusion, and the unfavorable dynamics of the value of consciousness in this case corresponded to a decrease in the amplitude and greater latency of P2N2 peaks, reflecting insufficient activation of cortical structures during identification of the catalyst. The unfavorable direction is characterized by a decrease in the activation of the associative zones of the cortex during identification of the catalyst, an increase in heart rate variability, an increase in the spectral power of fluctuations reflecting the energy of suprasegmental centers of vegetative regulation. Thus, the inclusion of additional neurophysiological predictors allowed us to make a better model for predicting the course of the acute period of hemorrhagic infarction. Modern applied mathematical data processing technologies make it possible to effectively solve the problem of systematization of early outcomes in patients with hemorrhagic infarction. In addition, the introduction of methods of multidimensional statistics (cluster analysis and the doctrine of the artificial origin of neural networks) allows us to rank the studied characteristics, identify more important ones and build predictive models based on them. Machine learning methods make it possible to create methods for predicting the significance of patients' consciousness, the

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acute period of formation of intracerebral hematomas of supratentorial localization,
the likely formation of disease outcomes in patients with non-traumatic intracerebral hematomas based on the characteristics of neurophysiological characteristics, and also the volume of the hematoma. The most significant factors for the prognosis of hemorrhagic stroke are: hematoma volume; parameters reflecting the relationship of cortical-subcortical structures and regulation of the functional state of the brain (frontal structures – indicators of the frequency and power of theta oscillations), neurophysiological correlates of recognition of the presented stimulus (peak amplitude P2N2 P300 and latency N2); characteristics of the central mechanisms of autonomic regulation of activity (power spectrum of HRV oscillations in the range of very low frequency oscillations).

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