Prediction of the functional outcome of cerebral ischemic supratentorial stroke acute period on the basis of spectral analysis of the brain bioelectrical activity

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Key words: brain infarction, electroencephalography, prognosis.

The purpose of this study was to determine the most informative parameters of the brain bioelectrical activity spectral analysis for the functional outcome of cerebral ischemic supratentorial stroke (CISS) acute period prediction.

Materials and methods. Prospective, cohort and comparative study was conducted among 103 patients in CISS acute period (61 men and 42 women, mean age was 67.7 ± 0.8 years). Electroencephalographic study was conducted on the 2–3rd day of the disease with the use of 19-channel electroencephalographic scanner. The values of absolute spectral rhythm power of delta (0.5–4.0 Hz), theta (4–8 Hz), alpha (8–13 Hz), beta (13–35 Hz), theta1 (4–6 Hz), theta2 (6–8 Hz), alpha1 (8–10 Hz), alpha2 (10–13 Hz), beta1 (13–25 Hz) and beta2 (25–35 Hz) bands in the affected hemisphere (AH) and intact hemisphere (IH) were determined. The relative spectral rhythm power (RSRP), fronto-occipital rhythm gradient (FORG) and the severity of interhemispheric rhythm asymmetry (IHRA) were calculated. The functional outcome of the disease acute period was assessed on the 21st day on the basis of the modified Rankin Scale (mRS), while the value of mRS score >3 was considered as an unfavourable functional outcome.

Results. Unfavourable functional outcome of the CISS acute period was registered in 46 (44.6 %) patients. In accordance with the data of multivariate regression analysis it was determined that RSRP of delta band in the IH (OR 95 % CI = 1.31 (1.13–1.52), P = 0.0004), FORG of alpha band in the AH (OR 95 % CI = 29.07 (1.86–455.15), P = 0.0024) and IHRA of alpha band (OR 95 % CI = 0.01 (0.0001–0.80), P = 0.0402) were independently associated with functional outcome of the CISS acute period. The RSRP of delta band in the IH > 18.4 % (Se = 87.0 %, Sp = 77.7 %, AUC 95 % CI = 0.94 (0.87–0.98), P < 0.0001), FORG of alpha band in the AH > 0.066 (Se = 67.4 %, Sp = 70.0 %, AUC 95 % CI = 0.74 (0.65–0.82), P<0.0001) and IHRA alpha band ≤ 0.066 (Se = 60.9 %, Sp = 70.2 % AUC 95 % CI = 0.66 (0.56–0.75), P < 0.0039) were the optimal cut-off values as for the unfavourable functional prognosis of CISS acute period.

Conclusions. The RSRP of delta band in the IH, FORG of alpha band in the AH and the IHRA of alpha band are the most informative parameters of the brain bioelectrical activity spectral analysis for the prediction of the functional outcome of cerebral ischemic supratentorial stroke acute period.

Прогнозування функціонального виходу гострого періоду мозкового ішемічного супратенторіального інсульту на підставі спектрального аналізу біоелектричної активності головного мозку

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Мета роботи — визначити найбільш інформативні параметри спектрального аналізу біоелектричної активності головного мозку для прогнозування функціонального виходу гострого періоду мозкового ішемічного супратенторіального інсульту (МІСІ).

Матеріали та методи. Виконано проспективне, когортне, порівняльне дослідження 103 пацієнтів у гостром періоді МІСІ (61 чоловік і 42 жінки, середній вік — 67,7 ± 0.8 року). Рівень неврологічного дефіциту оцінювали за National Institute of Health Stroke Scale. Електроенцефалографічне дослідження виконали на 2–3 добу захворювання. Окремо для ураженої півкулі (УП) і неураженої півкулі (НП) встановлювали значення абсолютної спектральної потужності, відносної спектральної потужності, а також значення тета1 (4–6 Гц), тета2 (6–8 Гц), альфа1 (8–10 Гц), альфа2 (10–13 Гц) і бета1 (13–25 Гц) спектральних ритмів та лобно-потиличних градієнтів ритмів (ЛПГР) і вираженість міжпівкульної асиметрії (МПАР). Функціональний вихід гострого періоду МІСІ оцінювали на 21 добу захворювання за модифікованою шкалою Ренкіна (мШР), при цьому несприятливим функціональним виходом були значення >3 бали за мШР.

Результати. Несприятливий функціональний вихід зафіксовано у 46 (44,6 %) пацієнтів. На підставі мультиваріантного логістичного регресійного аналізу визначено параметри спектрального аналізу електроенцефалографічного паттерну, які є найбільш інформативними для прогнозування функціонального виходу гострого періоду мозкового ішемічного супратенторіального інсульту: РСРД дельта-банди у ІП (OR 95 % ДІ = 1,31 (1,13–1,52), р = 0,0004), РСРД альфа-банди у АП (OR 95 % ДІ = 29,07 (1,86–455,15), р = 0,0024) та РСРД альфа-банди у ІП (OR 95 % ДІ = 0,01 (0,0001–0,80), р = 0,0402), при цьому оптимальними точками відсікання значень названих параметрів були значення 18,4 % (Se = 87,0 %, Sp = 77,7 %, AUC 95 % ДІ = 0,94 (0,87–0,98), P < 0,0001) для РСРД дельта-банди у ІП, 0,066 (Se = 67,4 %, Sp = 70,0 %, AUC 95 % ДІ = 0,74 (0,65–0,82), P<0,0001) для РСРД альфа-банди у АП та 0,066 (Se = 60,9 %, Sp = 70,2 %, AUC 95 % ДІ = 0,66 (0,56–0,75), P < 0,0039) для РСРД альфа-банди у ІП.

Висновки. Найбільш інформативними параметрами спектрального аналізу біоелектричної активності головного мозку для прогнозування функціонального виходу гострого періоду МІСІ є відносна спектральна потужність ритмів дельта-банди у ІП, значення тета1 та тета2 спектральних ритмів у АП та відносна спектральна потужність ритмів альфа1 та альфа2 спектральних ритмів у ІП.
Introduction
Cerebral ischemic supratentorial stroke (CISS) as the most common form of cerebrovascular pathology is a global problem of modern times. Its special medical and social significance is due to the leading positions in the structure of death and disability causes in most countries of the world [1–3]. One of the most appropriate means to improve the effectiveness of treatment activities in patients with CISS is a differentiated approach development for the optimal tactics selection on the basis of an individual prognosis [4–5].

All of the mentioned above justifies the necessity of brain damage severity objectification at the onset of CISS. Electroencephalography (EEG) is one of the most informative methods to study the brain functional state. This method is highly sensitive to changes in brain bioelectrical activity that are induced by focal cortical ischemia [6–8]. In combination with a millisecond time resolution, that is impossible to be used in diffusion-mediated magnetic resonance imaging and positron emission tomography [9], it explains the fact that EEG has been used for more than 40 years for cerebral ischemia detection during carotid surgery [10]. Additional advantages of the method are: non-invasiveness and absence of contraindications. Quantitative (spectral) analysis of EEG pattern allows increasing the diagnostic informative value of the method [11–14]. At the same time, the unified criteria for the determination of the short-term functional prognosis of CISS acute period outcome, which take into consideration the results of spectral analysis of the brain spontaneous bioelectrical activity, are currently absent, and the purpose of this study was to determine the most informative parameters of spectral analysis of the electroencephalographic pattern for the functional outcome of cerebral ischemic supratentorial stroke acute period prediction.

Materials and methods
Prospective, cohort and comparative study was conducted among 103 patients in CISS acute period (61 men and 42 women, mean age was 67.7 ± 0.8 years), who were hospitalized within the first 24 hours from the onset of the disease and who did not undergo thrombolytic therapy.

CISS pathogenic subtype was determined in accordance with the Trial of Org 10172 in Acute Stroke Treatment (TOAST) criteria [15]. Clinical and neurological study included the neurological deficit level assessment using National Institute of Health Stroke Scale (NIHSS) in acute period dynamics. The visualization of cerebral structures was made with the help of CT scanner “Siemens Somatom Spirit” (Germany). The lesion size and the displacement of brain median structures were assessed.

The study excluded patients with acute cerebral circulation disorders, craniocerebral injury and epileptic seizures in the anamnesis, combined with the cerebral hemorrhage, hemorrhagic transformation of brain infarction, oncologic and/or decompensated somatic pathology.

Electroencephalographic study was conducted on the 2nd–3rd day of the disease with the use of 19-channel
Table 1. Relative spectral rhythm power, fronto-occipital rhythm gradient and interhemispheric asymmetry values in patients with CISS on the 2nd–3rd day of the disease, Me (IQR)

| Indexes | Affected hemisphere | Intact hemisphere |
|---------|---------------------|-------------------|
| RSRP of delta band, % | 18.0 (10.1; 34.9) | 17.3 (10.2; 26.3) |
| RSRP of theta1 band, % | 10.7 (7.2; 14.4) | 9.7 (6.6; 12.7) |
| RSRP of theta2 band, % | 12.6 (8.2; 17.5) | 11.6 (8.0; 19.2) |
| RSRP of theta band, % | 24.4 (18.1; 30.6) | 21.9 (16.9; 32.3) |
| RSRP of alpha1 band, % | 16.8 (9.9; 25.2) | 18.1 (12.5; 28.0) |
| RSRP of alpha2 band, % | 8.3 (5.4; 13.2) | 9.5 (6.3; 15.6) |
| RSRP of alpha band, % | 27.2 (17.0; 41.6) | 31.7 (22.5; 43.2) |
| RSRP of beta1 band, % | 14.5 (8.8; 22.1) | 14.8 (9.1; 22.8) |
| RSRP of beta2 band, % | 3.5 (1.9; 6.3) | 3.2 (1.7; 5.4) |
| RSRP of beta band, % | 18.6 (10.9; 29.0) | 18.6 (11.8; 28.6) |
| FORG of delta band | 0.053 (-0.152; 0.192) | 0.047 (-0.091; 0.171) |
| FORG of theta1 band | 0.135 (-0.055; 0.296) | 0.112 (-0.022; 0.228) |
| FORG of theta2 band | 0.040 (-0.122; 0.258) | 0.064 (-0.125; 0.205) |
| FORG of theta band | 0.004 (-0.085; 0.240) | 0.061 (-0.057; 0.187) |
| FORG of alpha1 band | -0.092 (-0.328; 0.147) | -0.163 (-0.366; 0.010) |
| FORG of alpha2 band | -0.038 (-0.229; 0.130) | -0.201 (-0.359; 0.020) |
| FORG of alpha band | -0.099 (-0.283; 0.097) | -0.203 (-0.396; 0.024) |
| FORG of beta1 band | 0.103 (0.001; 0.283) | 0.072 (-0.031; 0.175) |
| FORG of beta2 band | 0.247 (0.066; 0.440) | 0.170 (-0.021; 0.371) |
| FORG of beta band | 0.144 (-0.037; 0.314) | 0.103 (-0.014; 0.217) |
| IHRA of delta band | 0.084 (-0.056; 0.219) | |
| IHRA of theta1 band | 0.092 (-0.043; 0.209) | |
| IHRA of theta2 band | 0.055 (-0.090; 0.196) | |
| IHRA of theta band | 0.065 (-0.041; 0.189) | |
| IHRA of alpha1 band | -0.026 (0.104; 0.123) | |
| IHRA of alpha2 band | -0.033 (0.184; 0.081) | |
| IHRA of alpha band | -0.040 (-0.171; 0.102) | |
| IHRA of beta1 band | 0.001 (-0.069; 0.108) | |
| IHRA of beta2 band | 0.050 (-0.048; 0.208) | |
| IHRA of beta band | 0.032 (-0.070; 0.109) | |

Table 2. The analysis of EEG pattern rhythm structure (%) in patients with CISS on the 2nd–3rd day of the disease versus the acute period outcome of the disease, Me (IQR)

| Indexes | Unfavourable functional outcome (n = 46) | Favourable functional outcome (n = 57) | P |
|---------|------------------------------------------|---------------------------------------|---|
| RSRP of delta band AH | 37.9 (20.3; 43.4) | 10.1 (7.5; 14.7) | <0.0001 |
| RSRP of theta1 band AH | 11.4 (8.7; 16.3) | 8.9 (6.4; 13.8) | 0.0226 |
| RSRP of theta2 band AH | 13.5 (8.7; 17.8) | 11.4 (7.4; 14.2) | 0.2706 |
| RSRP of theta band AH | 24.9 (22.4; 34.1) | 21.9 (15.1; 26.7) | 0.0196 |
| RSRP of alpha1 band AH | 10.3 (8.2; 15.5) | 22.3 (17.2; 31.6) | <0.0001 |
| RSRP of alpha2 band AH | 5.7 (4.5; 8.7) | 13.5 (8.3; 18.0) | <0.0001 |
| RSRP of alpha band AH | 17.3 (12.4; 24.3) | 40.8 (29.9; 47.4) | <0.0001 |
| RSRP of beta1 band AH | 11.0 (6.4; 16.6) | 20.5 (14.4; 26.8) | <0.0001 |
| RSRP of beta2 band AH | 2.3 (1.1; 5.7) | 3.9 (2.2; 8.3) | 0.0068 |
| RSRP of beta band AH | 13.6 (7.7; 22.4) | 25.5 (17.9; 33.8) | <0.0001 |
| RSRP of delta band IH | 28.4 (22.1; 39.8) | 9.5 (7.1; 13.1) | <0.0001 |
| RSRP of theta1 band IH | 10.0 (6.8; 13.9) | 8.5 (6.1; 11.6) | 0.1201 |
| RSRP of theta2 band IH | 13.5 (9.7; 20.0) | 10.1 (7.7; 14.2) | 0.0727 |
| RSRP of theta band IH | 25.1 (19.4; 36.2) | 19.3 (15.8; 24.0) | 0.0203 |
| RSRP of alpha1 band IH | 14.7 (10.1; 21.2) | 21.5 (16.4; 31.0) | 0.0029 |
| RSRP of alpha2 band IH | 8.0 (5.7; 12.7) | 14.9 (9.4; 23.0) | 0.0005 |
| RSRP of alpha band IH | 24.9 (17.3; 32.0) | 40.3 (31.9; 52.5) | <0.0001 |
| RSRP of beta1 band IH | 10.9 (7.6; 15.6) | 19.2 (13.8; 27.1) | <0.0001 |
| RSRP of beta2 band IH | 2.0 (1.3; 3.7) | 4.2 (2.5; 6.4) | 0.0002 |
| RSRP of beta band IH | 13.7 (8.9; 18.5) | 24.2 (17.2; 32.8) | <0.0001 |

Results of the study

Patients with brain infarction in the left hemisphere dominated in the studied cohort (62.1 %). Cerebral ischemic supratentorial stroke etiologic factors structure in accordance with TOAST classification was presented as follows: large-artery atherosclerosis (47.6 %), cardioembolism (18.4 %),
small-vessel occlusion (20.4 %) and stroke of undetermined etiology (13.8 %).

The total value in accordance with NIHSS score and infarct volume on admission constituted 9.0 (7.0; 14.0) and 20.6 (6.0; 59.2) mL, respectively, septum pellucidum displacement and pineal gland displacement were detected in 8 (7.8 %) patients.

The results of EEG pattern spectral analysis in patients with CISS on the 2nd–3rd day of the disease are shown in Table 1 and Table 2.

Unfavourable functional outcome (mRS score >3 on the 21st day of the disease) was detected in 46 (44.6 %) patients. Patients with an unfavourable functional CISS acute period outcome at onset of the disease has a higher severity of neurologic deficit in accordance with the NIHSS (14.5 (10.3; 16.0) versus 7.0 (6.0; 9.0), P < 0.0001) and a larger infarct volume (45.4 (15.7; 93.0) mL versus 11.4 (4.0; 37.1) mL, P = 0.0006).

The analysis of EEG pattern rhythm structure (%) was made in patients with CISS on the 2nd–3rd day of the disease versus the acute period outcome of the disease (Table 2).

The presented data shows that patients with an unfavourable functional outcome of CISS acute period had higher RSRP of delta band on the 2nd–3rd day of the disease (37.9 (30.3; 43.4) % versus 10.1 (7.5; 14.7) % in the AH; 28.4 (22.1; 39.8) % versus 9.5 (7.1; 13.1) % in the IH, P<0.0001 for both values) and RSRP of theta band (24.9 (22.4; 34.1) % versus 21.9 (15.1; 26.7) % in the AH; 25.1 (19.4; 36.2) % versus 19.3 (15.8; 24.0) % in the IH, P < 0.05 for both values) along with lower RSRP of alpha band (17.3 (12.4; 24.3) % versus 40.8 (29.9; 47.4) % in the AH; 24.9 (17.3; 32.0) % versus 40.3 (31.9; 52.5) % in the IH, P < 0.0001 for both values) and RSRP of beta band (13.6 (7.7; 22.4) % versus 25.5 (17.9; 33.8) % in the AH; 13.7 (8.9; 18.5) versus 24.2 (17.2; 32.8) % in the IH, P < 0.0001 for both values). The revealed changes in RSRP of alpha and delta bands dominated in the AH, whereas changes in RSRP of beta and theta bands had bilateral character. Rhythms of alpha and delta bands dominated in the EEG-structure in patients with favourable functional outcome of CISS acute period on the 2nd–3rd days of the disease.

The inversion of negative FORG of alpha, alpha1 and alpha2 bands in the AH was representative of patients with unfavourable functional outcome of CISS acute period, as well as a positive tendency of FORG of delta, beta, beta1 bands on the 2nd-3rd day of the disease, whereas the reduction of negative FORG of alpha2 band was detected in the intact hemisphere (Table 3).

Patients with CISS and unfavourable functional outcome on the 2nd and 3rd day of the disease had IHRA of alpha, alpha1 and alpha2 bands, which was proved by negative values of corresponding indexes (Table 4).

Parameters of EEG pattern spectral analysis were determined on the basis of the univariate logistic regression analysis. They were associated with the functional outcome of CISS acute period. Independent interrelation was determined only for 3 of them: RSRP of delta band in the IH (OR 95 % CI = 1.31 (1.13–1.52), P = 0.0004), FORG of alpha band in the AH (OR 95 % CI = 29.07 (1.86–455.15), P = 0.0224) and IHRA of alpha band (OR 95 % CI = 0.01 (0.0001–0.80), P = 0.0402) (Table 5).

Cut-off points for these indexes with optimal sensitivity and specificity interrelation were determined on the basis of the ROC-analysis for functional outcome of the disease acute period prognosis: RSRP of delta band in IH > 18.4 % (Se = 87.0 %, Sp = 87.7 %; AUC 95 % CI = 0.94 (0.87–0.98), P < 0.0001), FORG of alpha band in the AH > 0.066 (Se = 67.4 %, Sp = 70.0 %; AUC 95 % CI = 0.74 (0.65–0.82), P < 0.0001) and IHRA of alpha band ≤ 0.066 (Se = 60.9 %, Sp = 70.2 %; AUC 95 % CI = 0.66 (0.56–0.75), P < 0.0039).

The frequency distribution of unfavourable functional outcome of the CISS acute period in terms of RSRP of delta band in the IH, FORG of alpha band in the AH and IHRA of alpha band is shown in Table 6.

As a result, the RSRP of delta band in the IH > 18.4 %, FORG of alpha band in the AH > 0.066 and IHRA of alpha band (Se = 60.9 %, Sp = 70.2 %; AUC 95 % CI = 0.66 (0.56–0.75), P = 0.0039) were associated with increased risk of the unfavourable outcome of CISS acute period 7–21 (95 % CI 3.7–17.1, P = 0.0001), 2.4 (95 % CI 1.5–3.8, P = 0.0024) and 2.0 – fold (95 % CI 1.3–3.1, P = 0.0022), respectively.
### Table 5. Dependent and independent predictors of CISS acute period unfavourable functional outcome (univariate and multivariate models)

| Indexes                      | Univariate logistic regression model | Multivariate logistic regression model |
|------------------------------|-------------------------------------|---------------------------------------|
|                              | OR (95 % CI)                         | P                                    |
|                              |                                     |                                      |
| Admission NIHSS score        | 1.65 (1.37–1.98)                    | <0.0001                              |
| Infarct volume               | 1.02 (1.00–1.03)                    | 0.0056                               |
| RSRP of delta band AH        | 1.20 (1.13–1.28)                    | <0.0001                              |
| RSRP of theta1 band AH       | 1.08 (1.00–1.15)                    | 0.0233                               |
| RSRP of alpha1 band AH       | 0.89 (0.84–0.94)                    | <0.0001                              |
| RSRP of alpha2 band AH       | 0.78 (0.70–0.88)                    | <0.0001                              |
| RSRP of alpha band AH        | 0.89 (0.85–0.93)                    | <0.0001                              |
| RSRP of beta1 band AH        | 0.90 (0.85–0.95)                    | 0.0002                               |
| RSRP of beta2 band AH        | 0.87 (0.77–0.99)                    | 0.0337                               |
| RSRP of beta band AH         | 0.93 (0.89–0.97)                    | 0.0001                               |
| RSRP of delta band IH        | 1.35 (1.21–1.52)                    | <0.0001                              |
| RSRP of alpha1 band IH       | 0.95 (0.92–0.99)                    | 0.0091                               |
| RSRP of alpha2 band IH       | 0.89 (0.83–0.96)                    | 0.0011                               |
| RSRP of alpha band IH        | 0.93 (0.91–0.97)                    | 0.0001                               |
| RSRP of beta1 band IH        | 0.90 (0.85–0.95)                    | 0.0002                               |
| RSRP of beta2 band IH        | 0.77 (0.67–0.91)                    | 0.0026                               |
| RSRP of beta band IH         | 0.93 (0.88–0.98)                    | 0.0002                               |
| FORG of alpha1 band AH       | 15.36 (3.39–69.56)                  | 0.0004                               |
| FORG of alpha2 band AH       | 34.52 (4.86–245.31)                 | 0.0004                               |
| FORG of alpha band AH        | 34.91 (5.81–209.92)                 | 0.0001                               |
| FORG of beta1 band AH        | 9.23 (1.46–58.17)                   | 0.0180                               |
| FORG of alpha2 band IH       | 5.13 (1.08–24.42)                   | 0.0355                               |
| IHRA of alpha1 band          | 0.08 (0.01–0.54)                    | 0.0100                               |
| IHRA of alpha2 band          | 0.09 (0.01–0.81)                    | 0.0319                               |
| IHRA of alpha band           | 0.05 (0.01–0.43)                    | 0.0067                               |

### Table 6. Frequency distribution of unfavourable functional outcome of the CISS acute period in terms of RSRP of delta band in the IH, FORG of alpha band in the AH and IHRA of alpha band

| Parameters                  | Value | Number of patients | Unfavourable functional outcome of the CISS acute period (%) |
|-----------------------------|-------|--------------------|-------------------------------------------------------------|
| RSRP of delta band in IH, % | >18.4 | 47                 | 85.1                                                        |
|                             | ≤18.4 | 56                 | 10.7                                                        |
| FORG of alpha-range in AH   | >-0.066 | 48                | 64.6                                                        |
|                             | ≤-0.066 | 55                | 27.2                                                        |
| IHRA of alpha band          | ≤-0.066 | 45                | 62.2                                                        |
|                             | >-0.066 | 58                | 31.0                                                        |

### Discussion

Thus, on the basis of the EEG patterns spectral analysis comparative analysis it was determined that patients with the unfavourable outcome of CISS acute period on the 2nd–3rd day of the disease had a higher severity of bioelectric brain activity impairment in affected and intact hemispheres. This cohort of patients had higher values of RSRP of delta and theta bands and lower levels of RSRP of alpha and beta bands, whereas the increase in demonstrated changes severity was in the affected hemisphere. In addition, patients with the unfavourable outcome of CISS acute period on the 2nd–3rd day of the disease had ipsilateral reduction of zonal rhythm differences of alpha, alpha1 and alpha2 bands, which was due to a more severe depression of the absolute spectral power of the specified rhythms in caudal parts of the affected hemisphere. It was accompanied by the generation of interhemispheric asymmetry of absolute spectral rhythm power of alpha band and complied with the results of other studies.

Thus, in accordance with S. P. Finnigan et al. (2007) sub-acute delta/alpha power ratio (R = 0.91, P < 0.001) and relative alpha power (R = -0.82, P < 0.01) were significantly correlated with 30-day NIHSS score [16]. The study of R. V. Sheorapanday et al. (2011) determined that the EEG pairwise derived Brain Symmetry Index (pBSI) was significantly correlated with the modified Rankin Scale (mRS) score at month 6 (R = 0.46, P < 0.0005) [17]. In accordance with the data of X. Xin et al. (2017) poor functional outcomes were associated with higher BSI [18]. Our research studied the prognostic value of interhemispheric different frequency bands asymmetry indexes, while independent association with the functional outcome of CISS acute period was only determined for IHRA of alpha band. The prognostic value of FORG of alpha band in the AH on the 2nd–3rd day of CISS was proved, which confirms the advisability to define not only IHRA of alpha band, but also alpha-rhythm zonal differences in order to prognosticate the functional outcome of the disease acute period.

It should be noted, that the results of our study revealed the presence of RSRP delta-range of IH in the spectral of independent predictors of the unfavourable functional outcome of CISS acute period. It was also determined that this index has a higher informative value than IHRA of alpha band and the FORG of alpha band in the AH for the determination of a short-term functional prognosis. The obtained data complies with the results of other studies. Thus, in the study of G. Assenza et al. (2013), an increase in contralesional delta band power was mediated by interhemispheric disconnection providing negative prognosis in acute stroke [19]. In accordance with M. E. Wolf et al. (2017), generalized (but not focal) slowing were associated with clinical deterioration [20]. Thus, the intact hemisphere dysfunctional severity is also associated with the functional outcome of CISS acute period.

We determined the following cut-off points for the values of these indexes with the optimal sensitivity and specificity level for the functional outcome of CISS acute period prognosis: RSRP of delta band in the IH > 18.4 % (Se = 87.0 %, Sp = 87.7 %), FORG of alpha band in the AH > -0.066 (Se = 67.4 %, Sp = 70.0 %) and IHRA of alpha band ≤ -0.066 (Se = 60.9 %, Sp = 70.2 %). It is advisable to use the obtained criteria for the determination of a short-term functional prognosis as the basis for the optimization of therapy measures applied to patients with CISS.

### Conclusions

1. The following are the parameters which had the highest informative value as for EEG pattern spectral analysis on the 2nd–3rd day of CISS and which have an independent association with the functional outcome of the disease acute period: RSRP of delta band in the IH (OR 95 % CI = 1.31 (1.13–1.52), P=0.0004), FORG of alpha band in the AH (OR 95 % CI = 29.07 (1.86–455.15), P = 0.0224) and IHRA of alpha band (OR 95 % CI = 0.01 (0.0001–0.80), P = 0.0402).

2. Predictors of the unfavourable functional outcome of CISS acute period were the RSRP of delta band in the IH > 18.4 % (Se = 87.0 %, Sp = 87.7 %; AUC 95 %
CI = 0.94 (0.87–0.98), P < 0.0001; RR (95% CI) = 7.0 (3.7–17.1), P < 0.0001). FORG of alpha band in the AH > -0.066 (Se = 67.4%, Sp = 70.0%; AUC 95% CI = 0.74 (0.65–0.82), P < 0.0001; RR (95% CI) = 2.4 (1.5–3.8), P = 0.0004) and IHRA of alpha band ≤ -0.066 (Se = 60.9%, Sp = 70.2%; AUC 95% CI = 0.66 (0.56–0.75), P < 0.0039; RR (95% CI) = 2.0 (1.3–3.1), P = 0.0022) on the 2nd–3rd day of the disease.

The perspective for the further scientific research is the criteria of the unfavourable vital outcome of CISS acute period elaboration on the basis of EEG pattern spectral analysis.

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