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Relationships between changes in EEG and some metabolic parameters in patients of Truskavets' spa

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Abstract

Background. Earlier, we found relationships between EEG/HRV parameters and plasma/ urine electrolytes concentration in Truskavets' spa patients. The aim of this study is to analyze the relationships between ***changes*** in these parameters under the influence of balneotherapy. **Materials and Methods**. The object of observation were 22 men (23-70 years), who underwent rehabilitation treatment of chronic pyelonephritis and cholecystitis in remission. The examination was performed twice, before and after a 9-11-day course of balneotherapy. The object of the study were the parameters of the EEG and exchange of electrolytes and nitric metabolites. **Results**. Judging by the coefficient of determination, changes in the concentrations of electrolytes and nitric metabolites in the urine and plasma are mediated by changes in neurodynamics by 99,8 % and 99,4% respectively. **Conclusion**. Balneotherapy affects the exchange of electrolytes and nitrogen metabolites through the CNS.

Keywords: Truskavets' spa, chronic pyelonephritis and cholecystitis, EEG and metabolic parameters, relationships.

INRODUCTION

Earlier, we found close canonical correlations between EEG/HRV parameters, on the one hand, and plasma and urine electrolytes, on the other hand, in Truskavets' spa patients [5,7]. The aim of this study is to analyze the relationships between ***changes*** in these parameters under the influence of balneotherapy.

MATERIALS AND METHODS

The object of clinical-physiological observation were 22 men aged 23-70 years, who underwent rehabilitation treatment in the Truskavets' spa of chronic pyelonephritis and cholecystitis in remission accompanied of neuroendocrine-immune complex dysfunction. The examination was performed twice, before and after a 9-11-day course of balneotherapy. Patients received standard balneotherapeutic complex: bioactive water Naftussya (3 ml/kg one hour before meals three times a day) and in half an hour additionally drank water "Mariya" in the same dose as well as application of Ozokerite on the lumbar region (temperature 45^0C, exposure 30 minutes, every other day, 5 procedures) and baths with mineral water (Cl^--SO_4^{2-}-Na^+-Mg^{2+} containing salt concentration 25 g/L, temperature 36-37^0C, duration 8-10 minutes, every other day, 5 procedures).

The day before, daily urine was collected, in which was determined the concentration of electrolytes: calcium (by reaction with arsenase III), magnesium (by reaction with colgamite), phosphates (phosphate-molybdate method), chloride (mercury-rhodanidine method), sodium and potassium (flamming photometry) as well as nitric metabolites: creatinine (by Jaffe's color reaction by Popper's method) and uric acid (uricase method).

Urine lithogenicity index (Lith) was also calculated by the formula [2]:

$$Lith = (Uric\ acid \bullet Calcium/Magnesium \bullet Creatinine)^{0,25}.$$

The same metabolic parameters were determined in plasma.

The analysis carried out according to instructions [3] with the use of analyzers "Reflotron" (BRD) and "Pointe-180" (USA) and corresponding sets of reagents.

In basal conditions we recorded EEG a hardware-software complex "NeuroCom Standard" (KhAI MEDICA, Kharkiv, Ukraine) monopolar in 16 loci (Fp1, Fp2, F3, F4, F7, F8, C3, C4, T3, T4, P3, P4, T5, T6, O1, O2) by 10-20 international system, with the reference electrodes A and Ref on the earlobes. The duration of the epoch was 25 sec. Among the options considered the average EEG amplitude (μV), average frequency (Hz), frequency deviation (Hz) as well as absolute (μV^2/Hz) and relative (%) power spectrum density (PSD) of basic rhythms: β (35÷13 Hz), α (13÷8 Hz), θ (8÷4 Hz) and δ (4÷0,5 Hz) in all loci, according to the instructions of the device. In addition, calculated Laterality Index (LI) for PSD each Rhythm using formula:

$$LI, \% = \Sigma\ [200 \bullet (Right - Left)/(Right + Left)]/8.$$

We calculated also for each locus EEG Shannon's CE [15] entropy (h) of normalized PSD using Popovych's IL [4,8,14] formula:

$$hEEG = -\ [PSD\alpha \bullet \log_2 PSD\alpha + PSD\beta \bullet \log_2 PSD\beta + PSD\theta \bullet \log_2 PSD\theta + PSD\delta \bullet \log_2 PSD\delta]/\log_2 4$$

For statistical analysis used the software package "Statistica 64".

RESULTS AND DISCUSSION

According to the results of screening the correlations between changes in EEG parameters, on the one hand, and the concentration of electrolytes and nitrogenous metabolites in the urine, on the other hand, a matrix was created, which includes only EEG parameters with significant links (Table 1).

Table 1. Matrix of correlations between changes in EEG and urine variables

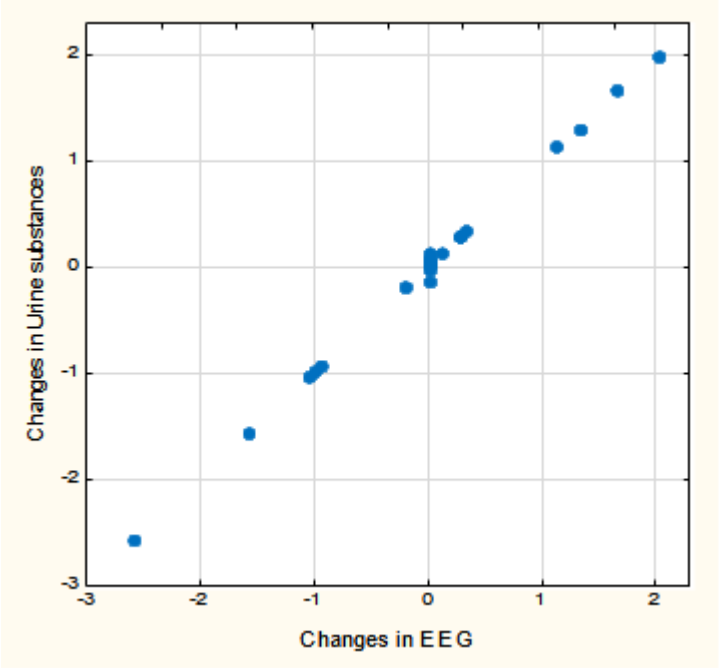
Variables	Nau	Clu	Cau	Mgu	Ku	Pu	Cru	Uru	Lith
F7-δ PSD, μV^2/Hz	0,69	0,50	-0,15	-0,03	0,15	0,14	-0,07	-0,16	-0,08
T6-δ PSD, μV^2/Hz	0,58	0,30	-0,44	-0,25	0,00	0,04	-0,06	-0,10	-0,28
F8-δ PSD, %	0,58	0,24	-0,52	-0,21	-0,02	0,17	-0,05	-0,12	-0,45
F7-δ PSD, %	0,41	0,10	-0,67	-0,39	0,02	0,08	-0,02	-0,11	-0,50
T5-δ PSD, μV^2/Hz	0,29	-0,04	-0,56	-0,34	-0,18	-0,10	-0,01	0,01	-0,37
O2-δ PSD, μV^2/Hz	0,24	-0,03	-0,63	-0,31	-0,20	0,04	0,01	0,03	-0,45
Deviation δ, Hz	-0,49	-0,16	0,59	0,12	-0,13	-0,11	0,01	0,11	0,57
Entropy F7	-0,67	-0,26	0,39	0,11	-0,26	0,02	0,02	0,08	0,30
Entropy T6	-0,54	-0,11	0,47	0,24	-0,11	0,01	0,02	0,05	0,34
Entropy Fp2	-0,53	-0,18	0,32	0,15	-0,17	0,12	0,05	0,04	0,16
Entropy O2	-0,31	0,07	0,59	0,32	-0,14	0,21	-0,03	-0,03	0,44
F8 β PSD, %	-0,50	-0,33	0,32	0,10	0,15	-0,26	0,04	0,10	0,30
F4-α PSD, %	-0,07	-0,09	0,37	0,49	0,08	0,12	0,11	0,08	0,13
Laterality β, %	-0,47	-0,35	-0,04	-0,21	-0,24	-0,14	-0,02	0,14	0,15

Note. According to the formula: $|r| \geq \{exp[2t/(n-1,5)^{0,5}] - 1\}/\{exp[2t/(n-1,5)^{0,5}] + 1\}$, for a sample of 22 observations critical value of correlation coefficient module at $p<0,05$ ($t>2,09$) is 0,43, at $p<0,02$ ($t>2,53$) is 0,50, at $p<0,01$ ($t>2,84$) is 0,56, at $p<0,001$ ($t>3,85$) is 0,69.

Next, the canonical correlation between the two sets of balneotherapy effects is analyzed. The program included in the canonical roots not all elements of the matrix (Table 2). Due to the pseudo-staining, the main mediating role in the effect of balneotherapy on the electrolytes of the urine parameters of **delta** rhythm and **entropy** is clearly visible. In this case, the delta-rhythm-generating neurons localized in different loci up-regulate changes in sodium, chloride and less potassium concentrations, while delta-rhythm frequency variability, beta-rhythm-generating neurons projected at the F8 locus, EEG entropy as well as right-hand shift of beta-rhythm symmetry (not included in the model), carry out down-regulation. In contrast, changes in urinary concentrations of uric acid and calcium (mostly) as well as magnesium and creatinine (less) are object to opposite regulatory effects of these nerve structures as well as of alpha-rhythm generating neurons projected at the F4 locus. Judging by the coefficient of determination, changes in the concentrations of electrolytes and nitric metabolites in the urine caused by balneotherapy are mediated by changes in neurodynamics by 99,8% (Fig. 1).

Table 2. Factor structure of EEG and urinary electrolytes roots changes

EEG Variables	R
F7-δ PSD, μV^2/Hz	-0,523
T6-δ PSD, μV^2/Hz	-0,375
F8-δ PSD, %	-0,339
F7-δ PSD, %	-0,271
T5-δ PSD, μV^2/Hz	-0,079
O2-δ PSD, μV^2/Hz	-0,015
Deviation δ, Hz	0,335
F8 β PSD, %	0,217
Entropy F7	0,554
Entropy Fp2	0,437
Entropy T6	0,400
Entropy O2	0,267
F4-α PSD, %	0,069
Electrolytes Urine	**R**
Na, mM/L	-0,841
K, mM/L	-0.809
Cl, mM/L	-0,411
Uric acid, μM/L	0,180
Ca, mM/L	0,153
Mg, mM/L	0,034
Creatinine, μM/L	0,099



R=0,999; R^2=0,998; $\chi^2_{(91)}$=125; p=0,010; Λ Prime<10^{-5}

Fig. 1. Scatterplot of canonical correlation between changes in EEG parameters (X-line) and Urine electrolytes&nitric metabolites concentration (Y-line)

Interestingly, the dynamics of lithogenicity of urine is unidirectional with the dynamics of only the concentration of calcium in it.

According to a similar algorithm, the relationships between changes in EEG parameters and the concentration of electrolytes and nitrogen metabolites in plasma were analyzed (Tables 3 and 4).

Table 3. Matrix of correlations between changes in EEG and Plasma variables

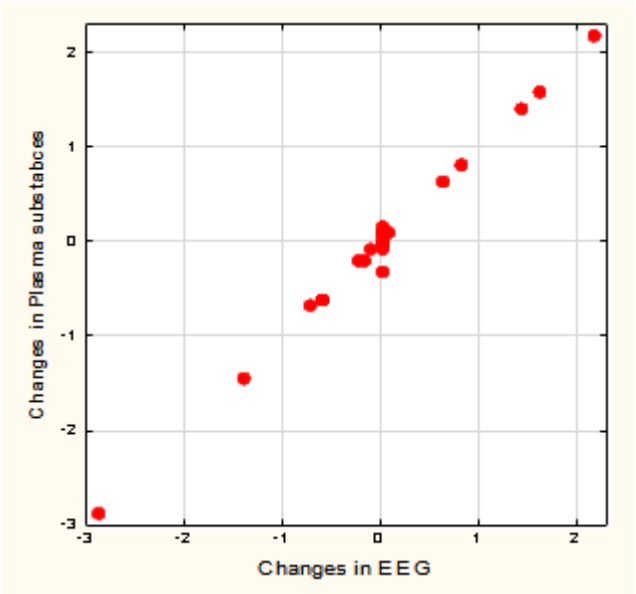
Variables	Mgp	Urp	Clp	Nap	Crp	Kp	Pp	Cap
T5-δ PSD, μV²/Hz	**0,90**	0,16	0,39	0,39	0,15	-0,19	-0,38	-0,26
T6-δ PSD, μV²/Hz	**0,85**	0,29	0,27	0,27	0,19	-0,36	**-0,59**	-0,08
O2-δ PSD, μV²/Hz	**0,77**	0,38	0,19	0,19	0,04	-0,20	**-0,50**	-0,11
F7-δ PSD, μV²/Hz	**0,63**	0,29	0,19	0,19	0,22	-0,38	**-0,57**	0,03
F7-δ PSD, %	**0,81**	0,12	0,26	0,26	0,26	**-0,54**	-0,42	-0,20
F8-δ PSD, %	**0,76**	0,11	0,19	0,19	0,14	-0,41	**-0,56**	-0,12
Deviation δ, Hz	**-0,50**	**-0,43**	-0,23	-0,23	-0,32	0,41	0,28	-0,04
F8 β PSD, %	**-0,67**	-0,08	-0,14	-0,14	0,01	0,29	**0,72**	0,23
Entropy F7	**-0,71**	-0,41	-0,20	-0,20	-0,31	0,37	0,30	-0,21
Entropy O2	**-0,69**	-0,38	-0,16	-0,16	-0,11	0,23	0,28	-0,10
Entropy T6	**-0,74**	-0,24	-0,16	-0,16	-0,19	0,32	0,28	-0,16
Entropy Fp2	**-0,67**	-0,36	-0,26	-0,26	-0,27	0,24	0,24	-0,16
F4-α PSD, %	-0,39	-0,04	-0,05	-0,05	-0,07	0,19	0,24	0,09
Laterality β, %	-0,20	-0,13	-0,16	-0,16	-0,37	0,37	0,03	-0,00

Table 4. Factor structure of EEG and Plasma variables roots changes

EEG Variables	R
T5-δ PSD, μV²/Hz	0,714
O2-δ PSD, μV²/Hz	0,691
T6-δ PSD, μV²/Hz	0,614
F7-δ PSD, %	0,463
F8-δ PSD, %	0,460
F7-δ PSD, μV²/Hz	0,408
F8 β PSD, %	-0,490
F4-α PSD, %	-0,249
Entropy O2	-0,524
Entropy Fp2	-0,464
Entropy F7	-0,440
Entropy T6	-0,422
Deviation δ, Hz	-0,370
Plasma Variables	**R**
Mg, mM/L	0,698
Uric acid, μM/L	0,546
Cl, mM/L	0,536
Na, mM/L	0,536
K, mM/L	0,166
Creatinine, μM/L	0,030
Phosphates, mM/L	-0,555
Ca, mM/L	-0,417

It was found that the delta-rhythm-generating neurons up-regulate changes in magnesium, uric acid, sodium, chloride and less potassium and creatinine plasma concentrations, while delta-rhythm frequency variability, beta-rhythm-generating neurons projected at the F8 locus, alpha-rhythm generating neurons projected at the F4 locus as well as EEG entropy carry out down-regulation. In contrast, changes in concentrations of phosphates and calcium are object to opposite regulatory effects of these nerve structures and entropy.

Judging by the coefficient of determination, changes in the concentrations of electrolytes and nitric metabolites in the urine caused by balneotherapy are mediated by changes in neurodynamics by 99,4% (Fig. 1).



R=0,997; R^2=0,994; $\chi^2_{(91)}$=155; p<10^{-4}; Λ Prime<10^{-6}

Fig. 2. Scatterplot of canonical correlation between changes in EEG parameters (X-line) and Plasma component concentration (Y-line)

CONCLUSION

In practice, transcranial magnetic and direct current stimulation of the prefrontal and frontal scalp position is used to activate the dorsolateral prefrontal cortex nuclei [review: 1,6]. The figures presented by Winkelmann T et al [16] and Yoo HJ et al [17] give us reason to assume that the loci T5/T6 projected caudal anterior cingulate cortex. We assume that these structures directly (unlikely) or, more likely, through the autonomic and endocrine systems realize the effects of balneotherapy on the exchange of electrolytes and nitrogenous metabolites. In this study, we confirmed the previously identified regulatory ability of EEG entropy [4,8-12,18].

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ACCORDANCE TO ETHICS STANDARDS

Tests in patients are carried out in accordance with positions of Helsinki Declaration 1975, revised and complemented in 2002, and directive of National Committee on ethics of scientific researches. During realization of tests from all participants the informed consent is got and used all measures for providing of anonymity of participants.

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