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Electroencephalographic accompaniment of quantitative-qualitative blood pressure clusters in patients of Truskavets' spa

Nataliya V. Kozyavkina¹, Yuliya V. Vovchyna^{2,3}, Nataliya M. Voronych-Semchenko², Walery Zukow⁴, Igor L. Popovych^{1,5,6}

¹Kozyavkin Rehabilitation Clinic, Truskavets', Ukraine
nataliakozyavkina72@gmail.com; center@reha.lviv.ua

²Ivano-Frankivs'k National Medical University, Ivano-Frankivs'k, Ukraine

³Sanatorium "Kryshtalevyi Palats" SAD, Truskavets', Ukraine

⁴Nicolaus Copernicus University, Torun, Poland w.zukow@wp.pl

⁵Ukrainian Scientific Research Institute of Medicine of Transport, Odesa

⁶OO Bohomolets' Institute of Physiology, Kyiv i.popovych@biph.kiev.ua

Abstract

Background. Earlier we studied the autonomic and endocrine accompaniments of quantitative-qualitative blood pressure (BP) clusters of profile patients of Truskavets' spa. The **purpose** of this study is to clarify the electroencephalographic accompaniment in the same contingent. **Materials and methods.** Under an observations were 44 patients with chronic pyelonephritis and cholecystitis in the phase of remission. Testing was performed twice - on admission and after 7-10 days of standard balneotherapy. The main object of the study was BP (tonometer "Omron M4-I", Netherlands). EEG recorded a hardware-software complex "NeuroCom Standard" (KhAI Medica, Ukraine) monopolar in 16 loci. **Results.** The forward stepwise program identified 30 parameters as characteristic of quantitative-qualitative blood pressure clusters. In addition to BP parameters by default, 5 entropy parameters, 4 delta-rhythm, 6 theta-rhythm, 6 alpha-rhythm and 7 beta-rhythm parameters are included in the discriminant model. The most informative among them are PSD of beta-rhythm in C3 and C4 loci; alpha-rhythm in T4 and F3 loci; delta-rhythm in C3, T5 and P3 loci as well as its deviation. The accuracy of classification is 100%. **Conclusion.** The wide range of blood pressure - from low norm to arterial hypertension II - is accompanied by characteristic EEG conditions.

Keywords: blood pressure, electroencephalogram, discriminant analysis, Truskavets' spa.

INTRODUCTION

Earlier we showed that profile patients of Truskavets' spa are characterized by a wide range of blood pressure - from low norm to arterial hypertension III that correspond to the

hemodynamics parameters [5]. In next study we clarified the autonomic and endocrine accompaniments of quantitative-qualitative blood pressure clusters in the same contingent. We have been shown that the most informative among them are HRV-markers of sympathetic tone and sympathetic-vagal balance as well as testosterone and cortisol, whose levels are maximal in patients with hypertension II, while minimal in patients with low norm blood pressure, on the one hand, and markers of vagal tone and Kerdö's vegetative index, the levels of which are polar, on the other hand. The accuracy of patient classification is 98,9% [6][7].

The **purpose** of this study is to clarify the electroencephalographic accompaniment of quantitative-qualitative blood pressure clusters in the same contingent. The results of a pilot study on this topic were previously published [3][4][10][13][14][15].

MATERIALS AND METHODS

Under an observations were 34 males and 10 females by age 24-76 years with chronic pyelonephritis and cholecystitis in the phase of remission. Testing was performed twice - on admission and after 7-10 days of standard balneotherapy (drinking of Naftussya bioactive water, applications of ozokerite, mineral pools).

The main object of the study was blood pressure (BP). Systolic and diastolic BP was measured (by tonometer "Omron M4-I", Netherlands) in a sitting position three times in a row. Retrospectively, 5 quantitative-qualitative blood pressure clusters were created (Fig. 1) according to the existing gradation [1][8].

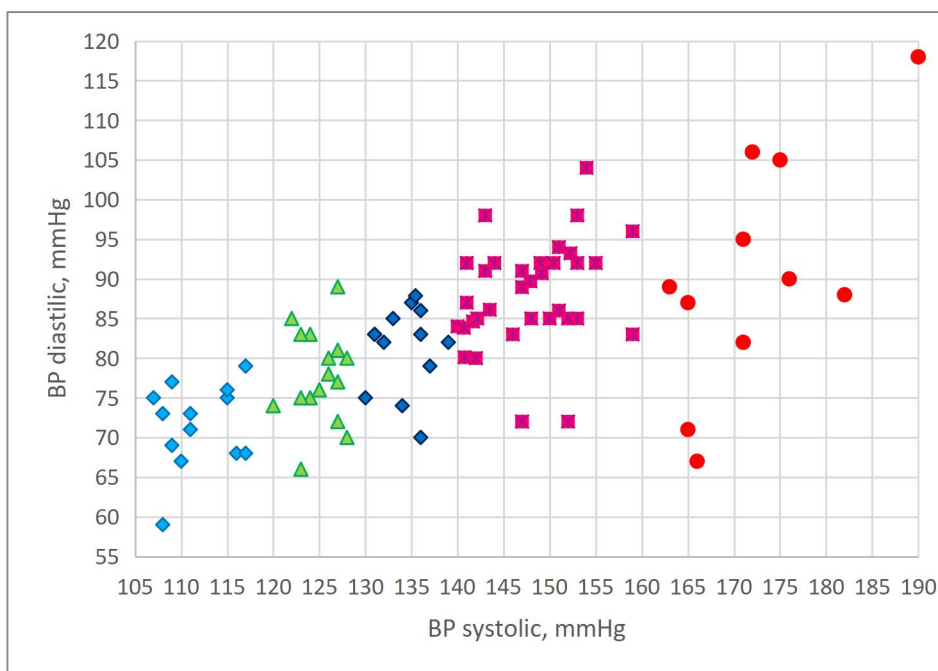


Fig. 1. Diagram of scattering of systolic and diastolic blood pressure of patients of Truskavets' spa

EEG recorded 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. Two minutes after the eyes had been closed, 25 sec of artifact free EEG data were collected by computer. Among the options considered the average EEG amplitude (μV), average frequency (Hz), frequency deviation (Hz), index (%), absolute ($\mu\text{V}^2/\text{Hz}$) and relative (%) PSD of basic rhythms: β ($35 \div 13$ Hz), α ($13 \div 8$ Hz), θ ($8 \div 4$ Hz) and δ ($4 \div 0,5$ Hz) in all loci,

according to the instructions of the device. In addition, calculated coefficient of Asymmetry (As) and Laterality Index (LI) for PSD each Rhythm using formulas [9]:

$$As, \% = 100 \cdot (\text{Max} - \text{Min}) / \text{Min}; LI, \% = \Sigma [200 \cdot (\text{Right} - \text{Left}) / (\text{Right} + \text{Left})] / 8.$$

We calculated for each locus EEG the Entropy (h) of normalized PSD using Popovych's IL [11] formula based on classic Shannon's CE [12] formula:

$$h_{EEG} = - [\text{PSD}\alpha \cdot \log_2 \text{PSD}\alpha + \text{PSD}\beta \cdot \log_2 \text{PSD}\beta + \text{PSD}\theta \cdot \log_2 \text{PSD}\theta + \text{PSD}\delta \cdot \log_2 \text{PSD}\delta] / \log_2 4.$$

Reference values are taken from the database of our laboratory.

Results processed using the software package "Statistica 6.4".

RESULTS AND DISCUSSION

Following the pre-accepted algorithm, the recorded BP&EEG parameters were subjected to discriminant analysis [2]. The forward stepwise program identified 30 parameters as characteristic of quantitative-qualitative blood pressure clusters. In addition to BP parameters by default, 5 **entropy** parameters, 4 **delta-rhythm**, 6 **theta-rhythm**, 6 **alpha-rhythm** and 7 **beta-rhythm** parameters are included in the discriminant model. Another 2 EEG parameters were found to be out of the model, despite the clear recognition ability (Tables 1 and 2).

Table 1. Discriminant Function Analysis Summary for BP&EEG Variables, their actual levels (Mean±SE) for Clusters of Blood Pressure as well as Reference levels and Coefficients of Variability

Step 30, N of vars in model: 30; Grouping: 5 grs; Wilks' Λ : 0,0031; approx. $F_{(120)}=6,0$; $p<10^{-6}$

Variables currently in the model	Clusters of Blood Pressure (n)					Parameters of Wilk's Statistics					Reference (88)	Cv
	AH II (11)	AH I (35)	High N (13)	No-rm (16)	Low N (13)	Wilks' Λ	Partial Λ	F-remove (4,54)	p-level	Tolerance		
BP systolic, mmHg	172 2,5	148 0,9	134 0,8	125 0,6	112 1,0	0,027	0,113	106	10^{-6}	0,509	124,5 1,6	,122
BP diastolic, mmHg	90,7 4,5	87,6 1,2	81,3 1,5	77,8 1,5	71,5 1,5	0,004	0,770	4,03	0,006	0,484	79,0 0,7	,083
Entropy PSD C3	0,82 0,04	0,89 0,01	0,78 0,04	0,87 0,02	0,78 0,05	0,003	0,931	1,00	0,416	0,289	0,862 0,011	,115
Entropy PSD O2	0,76 0,06	0,81 0,02	0,78 0,04	0,67 0,05	0,75 0,03	0,004	0,707	5,582	0,001	0,140	0,776 0,015	,178
Entropy PSD P3	0,80 0,05	0,82 0,02	0,81 0,03	0,82 0,02	0,77 0,05	0,004	0,859	2,21	0,080	0,128	0,802 0,014	,167
Entropy PSD T3	0,83 0,04	0,90 0,01	0,75 0,04	0,78 0,04	0,76 0,05	0,003	0,889	1,68	0,168	0,361	0,857 0,012	,131
Entropy PSD T5	0,74 0,08	0,83 0,02	0,77 0,04	0,81 0,05	0,73 0,04	0,003	0,899	1,52	0,210	0,183	0,825 0,014	,156
Deviation- δ , Hz	0,64 0,07	0,70 0,04	0,55 0,04	0,66 0,08	0,85 0,10	0,004	0,807	3,23	0,019	0,611	0,67 0,03	,395
P3- δ PSD, %	25,2 6,0	27,7 2,8	26,0 5,6	24,8 3,5	36,7 7,1	0,004	0,805	3,27	0,018	0,120	25,6 1,9	,694
T5- δ PSD, %	32,5 9,2	25,8 3,2	29,9 7,0	40,9 6,0	41,6 8,2	0,003	0,942	0,835	0,509	0,065	26,3 1,9	,696
C3- δ PSD, %	30,4 6,8	27,9 2,7	37,5 7,5	28,8 3,3	43,5 7,4	0,004	0,792	3,56	0,012	0,098	28,0 1,8	,602
Amplitude- θ , μ V	7,7 1,0	9,7 0,9	7,7 0,6	9,4 0,9	8,6 1,0	0,004	0,861	2,18	0,083	0,287	7,75 0,3	,376
C4- θ PSD, %	9,4 1,1	13,9 1,1	9,5 1,4	9,8 1,1	11,9 1,3	0,004	0,750	4,50	0,003	0,157	11,1 0,5	,442
O1- θ	8,5	8,2	8,2	7,0	10,3	0,004	0,746	4,60	0,003	0,207	8,2	,584

PSD, %	1,6	0,8	1,4	0,9	1,7						0,5	
F8-θ	7,2	11,3	7,3	8,1	10,5	0,003	0,905	1,42	0,241	0,250	9,8	,492
PSD, %	1,2	1,2	0,6	1,3	2,0						0,5	
P4-θ	9,4	10,2	7,2	7,3	9,3	0,004	0,744	4,64	0,003	0,135	8,75	,545
PSD, %	1,6	0,9	0,8	0,7	1,3						0,5	
O2-θ	6,8	7,5	7,3	6,1	7,45	0,003	0,883	1,79	0,144	0,141	7,1	,554
PSD, %	1,3	0,8	1,4	0,9	1,4						0,4	
Index-α, %	49,5	48,4	47,3	62,6	53,4	0,004	0,795	3,47	0,014	0,125	50,7	,560
	8,5	5,7	8,7	6,0	6,6						3,0	
Deviation-α, Hz	0,86	1,11	0,91	0,81	1,23	0,004	0,835	2,67	0,042	0,500	1,02	,527
	0,10	0,12	0,10	0,10	0,15						0,06	
F7-α	28,9	27,1	21,1	18,4	26,6	0,004	0,776	3,89	0,008	0,168	27,6	,522
PSD, %	6,1	2,5	3,9	3,4	3,7						1,5	
T4-α	31,6	29,3	22,0	26,7	24,5	0,003	0,911	1,32	0,274	0,137	29,0	,500
PSD, %	5,9	2,5	4,4	3,1	4,7						1,6	
F3-α	31,6	29,5	30,1	30,9	27,0	0,004	0,766	4,12	0,006	0,061	33,2	,479
PSD, %	5,8	2,2	6,1	4,3	5,7						1,7	
Fp2-α	27,9	31,3	27,2	34,3	31,9	0,004	0,837	2,61	0,045	0,131	32,9	,448
PSD, %	4,2	2,4	4,1	4,7	5,1						1,6	
Laterality-β, %	-34	-3,1	-13,0	-13	-6,2	0,004	0,810	3,18	0,020	0,518	-0,9	SD
	6,4	4,7	10,8	5,5	7,2						3,6	34
T3-β	28,6	28,5	38,5	19,5	28,55	0,003	0,884	1,77	0,148	0,247	30,7	,462
PSD, %	3,7	2,1	6,1	3,3	5,1						1,5	
F3-β	25,5	27,0	27,8	15,6	17,1	0,003	0,949	0,73	0,575	0,264	26,7	,463
PSD, %	3,6	2,4	3,5	2,6	2,7						1,3	
O1-β	31,6	28,0	26,1	16,4	18,4	0,004	0,814	3,09	0,023	0,159	26,3	,542
PSD, %	4,8	3,2	4,4	3,1	2,7						1,5	
T5-β	26,4	31,2	35,4	19,9	24,9	0,004	0,863	2,14	0,088	0,061	29,0	,536
PSD, %	4,9	3,2	5,9	2,5	5,3						1,7	
C4-β	25,8	25,6	29,0	22,2	17,1	0,003	0,890	1,66	0,172	0,129	25,9	,405
PSD, %	3,2	1,8	3,9	3,3	2,2						1,1	
T4-β	26,6	29,3	39,7	24,5	26,9	0,003	0,919	1,18	0,329	0,198	30,4	,483
PSD, %	3,2	2,7	5,7	4,0	4,5						1,6	
Variables currently not in model	AH II (11)	AH I (35)	High N (13)	No-rm (16)	Low N (13)	Wilks' Λ	Partial Λ	F to enter	p-level	Tolerance	Reference (88)	Cv
Fp1-θ	9,4	13,4	6,65	7,7	10,8	0,003	0,985	0,21	0,933	0,203	10,4	,588
PSD, %	1,6	1,6	0,8	0,9	2,1						0,7	
C3-β	27,1	26,3	26,7	21,6	16,6	0,003	0,983	0,23	0,922	0,060	25,45	,420
PSD, %	3,6	2,0	3,8	2,8	2,4						1,1	

Table 2. Summary of Stepwise Analysis for BP&EEG Variables, ranked by criterion Λ

Variables currently in the model	F to enter	p-level	Λ	F-value	p-value
BP systolic, mmHg	298	10 ⁻⁶	0,065	298	10 ⁻⁶
T3-β PSD, %	3,83	0,007	0,055	67,0	10 ⁻⁶
Entropy PSD C3	3,73	0,008	0,046	39,2	10 ⁻⁶
C4-θ PSD, %	2,97	0,024	0,040	28,5	10 ⁻⁶
BP diastolic, mmHg	2,68	0,037	0,036	22,8	10 ⁻⁶
Deviation-δ, Hz	2,24	0,072	0,032	19,2	10 ⁻⁶
Laterality-β, %	2,06	0,094	0,029	16,7	10 ⁻⁶
F7-α PSD, %	1,95	0,111	0,026	14,9	10 ⁻⁶
P3-δ PSD, %	3,80	0,007	0,022	14,0	10 ⁻⁶
F3-β PSD, %	1,65	0,171	0,020	12,8	10 ⁻⁶

Index-α, %	2,00	0,104	0,018	11,9	10 ⁻⁶
O1-θ PSD, %	2,44	0,054	0,016	11,3	10 ⁻⁶
F8-θ PSD, %	2,58	0,045	0,014	10,8	10 ⁻⁶
Amplitude-θ, μV	1,33	0,268	0,013	10,1	10 ⁻⁶
Deviation-α, Hz	1,06	0,383	0,012	9,50	10 ⁻⁶
O1-β PSD, %	1,09	0,370	0,011	8,96	10 ⁻⁶
T5-β PSD, %	2,02	0,101	0,010	8,66	10 ⁻⁶
T5-δ PSD, %	1,32	0,271	0,009	8,28	10 ⁻⁶
Entropy PSD O2	1,51	0,209	0,009	7,97	10 ⁻⁶
T4-α PSD, %	1,24	0,302	0,008	7,66	10 ⁻⁶
F3-α PSD, %	1,39	0,246	0,007	7,39	10 ⁻⁶
Fp2-α PSD, %	2,03	0,102	0,006	7,25	10 ⁻⁶
P4-θ PSD, %	1,53	0,205	0,006	7,05	10 ⁻⁶
Entropy PSD P3	1,37	0,256	0,005	6,85	10 ⁻⁶
C3-δ PSD, %	1,54	0,202	0,005	6,69	10 ⁻⁶
C4-β PSD, %	1,42	0,239	0,004	6,52	10 ⁻⁶
Entropy PSD T3	1,63	0,180	0,004	6,40	10 ⁻⁶
O2-θ PSD, %	1,25	0,299	0,004	6,24	10 ⁻⁶
Entropy PSD T5	1,40	0,248	0,003	6,11	10 ⁻⁶
T4-β PSD, %	1,18	0,329	0,003	5,96	10 ⁻⁶

Next, the 30-dimensional space of discriminant variables transforms into 4-dimensional space of a canonical roots. For Root 1 $r^*=0,979$ (Wilks' $\Lambda=0,0031$; $\chi^2_{(120)}=402$; $p<10^{-6}$), for Root 2 $r^*=0,849$ (Wilks' $\Lambda=0,075$; $\chi^2_{(87)}=180$; $p=10^{-6}$), for Root 3 $r^*=0,722$ (Wilks' $\Lambda=0,270$; $\chi^2_{(56)}=91$; $p=0,002$) and for Root 4 $r^*=0,660$ (Wilks' $\Lambda=0,564$; $\chi^2_{(27)}=40$; $p=0,053$). The first root contains 84,1% of discriminative opportunities, the second 9,3%, the third 3,8%, the last 2,8%.

The calculation of the discriminant root values for each person as the sum of the products of raw coefficients to the individual values of discriminant variables together with the constant (Table 3) enables the visualization of each patient in the information space of the roots (Fig. 2).

Table 3. Standardized and Raw Coefficients and Constants for BP&EEG Variables

Coefficients	Standardized				Raw			
	Root 1	Root 2	Root 3	Root 4	Root 1	Root 2	Root 3	Root 4
Variables currently in the model								
BP systolic, mmHg	-1,344	0,105	-0,007	0,079	-0,277	0,022	-0,001	0,016
T3-β PSD, %	0,303	-0,053	-0,387	0,830	0,021	-0,004	-0,027	0,058
Entropy PSD C3	-0,163	-0,123	0,470	-0,447	-1,462	-1,099	4,211	-4,000
C4-θ PSD, %	0,141	0,866	-1,379	0,320	0,030	0,184	-0,292	0,068
BP diastolic, mmHg	0,258	-0,392	-0,688	-0,352	0,033	-0,049	-0,087	-0,044
Deviation-δ, Hz	0,068	0,249	0,660	-0,301	0,272	0,994	2,630	-1,199
Laterality-β, %	-0,030	0,469	-0,630	-0,060	-0,001	0,019	-0,025	-0,002
F7-α PSD, %	0,556	0,991	0,482	-0,687	0,040	0,071	0,035	-0,049
P3-δ PSD, %	0,269	0,945	-1,275	0,397	0,015	0,054	-0,073	0,023
F3-β PSD, %	-0,208	0,200	-0,465	-0,160	-0,019	0,018	-0,041	-0,014
Index-α, %	-0,506	1,370	-0,097	0,295	-0,019	0,052	-0,004	0,011
O1-θ PSD, %	-0,700	0,757	0,721	0,407	-0,157	0,170	0,162	0,091
F8-θ PSD, %	0,014	-0,482	-0,346	-0,586	0,003	-0,090	-0,065	-0,109
Amplitude-θ, μV	0,096	-0,737	-0,396	0,069	0,026	-0,199	-0,107	0,019
Deviation-α, Hz	0,242	0,507	-0,294	-0,317	0,502	1,051	-0,609	-0,658
O1-β PSD, %	-0,076	-1,016	0,892	-0,099	-0,005	-0,072	0,063	-0,007
T5-β PSD, %	0,069	1,562	-0,196	-1,020	0,004	0,098	-0,012	-0,064

T5-δ PSD, %	0,440	0,342	0,036	-1,193	0,019	0,015	0,002	-0,052
Entropy PSD O2	-0,104	1,683	0,092	0,241	-0,739	12,01	0,659	1,718
T4-α PSD, %	0,233	0,640	0,596	-0,522	0,016	0,045	0,042	-0,037
F3-α PSD, %	-0,342	1,410	-1,177	1,901	-0,021	0,087	-0,072	0,117
Fp2-α PSD, %	0,089	-1,063	-0,440	-0,850	0,006	-0,072	-0,030	-0,057
P4-θ PSD, %	-0,207	1,128	1,190	-0,676	-0,050	0,275	0,290	-0,165
Entropy PSD P3	0,030	-0,323	-1,067	0,992	0,249	-2,679	-8,846	8,231
C3-δ PSD, %	-0,408	1,555	0,570	0,348	-0,022	0,083	0,030	0,019
C4-β PSD, %	0,305	0,995	0,217	0,240	0,029	0,095	0,021	0,023
Entropy PSD T3	-0,109	-0,584	0,100	-0,312	-0,865	-4,636	0,872	-2,475
O2-θ PSD, %	0,258	-0,829	-0,716	0,109	0,063	-0,203	-0,176	0,027
Entropy PSD T5	0,335	-0,732	-0,109	-0,345	2,126	-4,646	-0,692	-2,189
T4-β PSD, %	-0,290	0,187	-0,648	0,432	-0,020	+0,013	-0,044	0,029
				Constants	35,88	-15,51	14,64	2,254
				Eigenvalues	23,58	2,587	1,088	0,774
				Cumulative proportions	0,841	0,934	0,972	1

Following the algorithm, at the next stage of the analysis, the actual values of the variables were recalculated into Z-scores (Table 4).

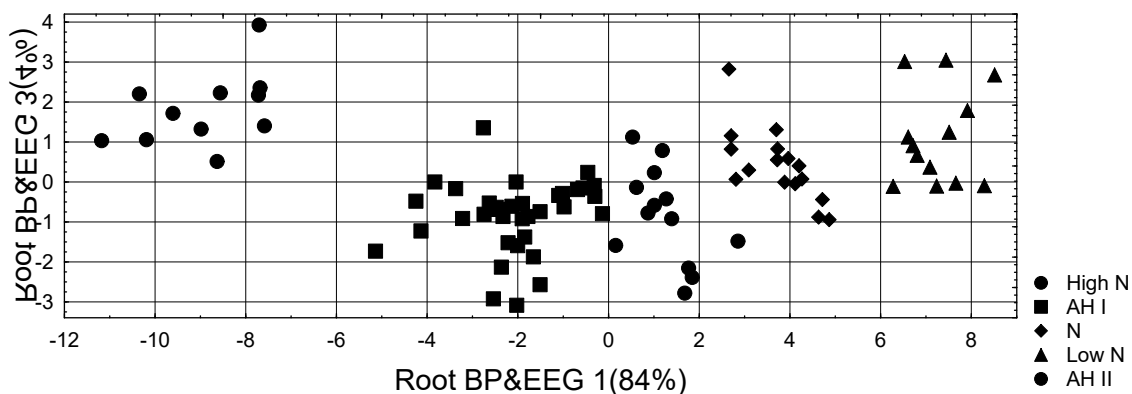
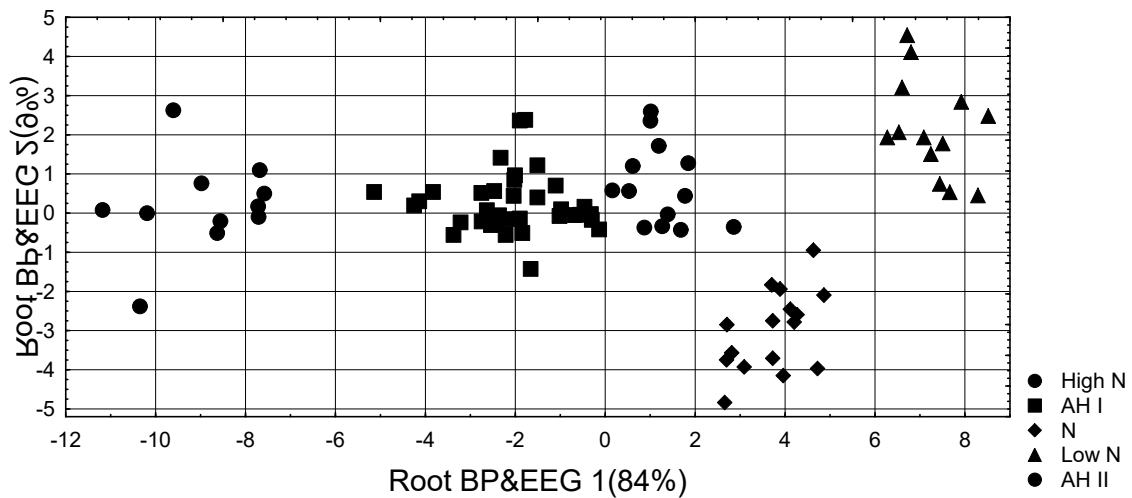
Table 4. Correlations Variables-Canonical Roots, Means of Roots and Z-scores of Blood Pressure and EEG Variables

Variables currently in the model	Correlations Variables-Roots				AH II (11)	AH I (35)	High N (13)	No-nrm (16)	Low N (13)
	R 1	R 2	R 3	R 4					
Root 1 (84,1%)	R 1	R 2	R 3	R 4	-8,9	-2,1	+1,2	+3,7	+7,3
BP systolic	-0,780	0,010	-0,079	-0,090	5,34	2,61	1,09	0,06	-1,42
BP diastolic	-0,162	-0,017	-0,231	-0,098	2,75	2,01	0,54	-0,29	-1,75
C4-β PSD	-0,046	-0,026	-0,164	0,184	-0,01	-0,02	0,29	-0,35	-0,84
C3-β PSD	currently not in the model				0,16	0,08	0,11	-0,36	-0,83
T4-α PSD	-0,032	-0,024	0,042	-0,116	0,18	0,02	-0,48	-0,15	-0,31
F3-α PSD	-0,011	-0,038	0,005	0,033	-0,10	-0,24	-0,20	-0,14	-0,39
C3-δ PSD	0,035	0,116	0,106	0,017	0,14	-0,01	0,33	0,04	0,92
T5-δ PSD	0,036	-0,042	0,162	-0,004	0,34	-0,03	0,20	0,80	0,84
Deviation-δ	0,032	0,089	0,102	-0,256	-0,13	0,10	-0,47	-0,05	0,67
P3-δ PSD	0,026	0,101	0,048	-0,086	-0,02	0,12	0,03	-0,04	0,63
Root 2 (9,3%)	R 1	R 2	R 3	R 4	+0,18	+0,25	+0,7	-3,0	+2,2
Entropy PSD O2	-0,028	0,152	-0,153	-0,027	-0,15	0,24	0,04	-0,78	-0,18
T3-β PSD	-0,014	0,168	-0,114	0,228	-0,15	-0,15	0,55	-0,79	-0,15
T5-β PSD	-0,021	0,109	-0,179	0,113	-0,16	0,15	0,42	-0,58	-0,26
T4-β PSD	-0,003	0,075	-0,159	0,228	-0,26	-0,07	0,64	-0,40	-0,24
F3-β PSD	-0,062	0,105	-0,202	0,114	-0,10	0,02	0,09	-0,90	-0,78
O1-β PSD	-0,068	0,087	-0,062	0,050	0,37	0,12	-0,01	-0,70	-0,56
F7-α PSD	-0,028	0,116	0,046	-0,115	0,09	-0,03	-0,45	-0,63	-0,07
Deviation-α	0,019	0,146	-0,044	-0,173	-0,29	0,17	-0,21	-0,39	0,39
O1-θ PSD	0,011	0,124	0,069	-0,039	0,05	-0,01	-0,01	-0,26	0,43
O2-θ PSD	-0,001	0,067	-0,046	-0,023	-0,08	0,11	0,05	-0,24	0,10
Index-α	0,021	-0,094	0,064	-0,037	-0,04	-0,08	-0,12	+0,42	0,09
Fp2-α PSD	0,018	-0,053	0,003	-0,106	-0,34	-0,11	-0,39	+0,09	-0,07
Entropy PSD P3	-0,012	-0,068	-0,093	-0,005	-0,02	0,17	0,06	+0,16	-0,26
Root 3 (3,8%)	R 1	R 2	R 3	R 4	+1,8	-0,85	-0,85	+0,4	+1,1
Laterality-β	0,043	0,041	-0,230	-0,169	-0,97	-0,07	-0,36	-0,37	-0,16
Entropy PSD T5	-0,006	-0,070	-0,155	-0,093	-0,64	0,05	-0,45	-0,15	-0,70
F8-θ PSD	0,013	0,072	-0,109	-0,250	-0,55	0,30	-0,52	-0,35	0,14

Root 4 (2,8%)	R 1	R 2	R 3	R 4	+0,4	-0,7	+1,9	0,0	-0,4
C4- θ PSD	-0,000	0,086	-0,175	-0,286	-0,34	+0,59	-0,34	-0,29	0,16
P4- θ PSD	-0,024	0,094	-0,011	-0,205	0,14	+0,31	-0,32	-0,30	0,12
Fp1- θ PSD	currently not in the model				-0,16	+0,50	-0,61	-0,44	0,06
Amplitude- θ	0,010	-0,051	-0,084	-0,165	-0,01	+0,65	-0,02	0,57	0,30
Entropy PSD T3	-0,057	0,012	-0,157	-0,294	-0,21	+0,42	-0,98	-0,70	-0,84
Entropy PSD C3	-0,023	-0,146	-0,155	-0,227	-0,44	+0,27	-0,80	0,10	-0,80

The localization along the first root axis of the patients with **Low Norm BP** (Fig. 2) in the extreme right (positive) zone reflects combination of minimum for sampling BP levels with **maximally suppressed** PSD of beta-rhythm in C3 and C4 loci and alpha-rhythm in T4 and F3 loci. At the opposite pole of the axis of the first root, there are patients with **AH II**, whose maximum BP is accompanied by normal and, as a rule, maximum levels for the sample of the listed variables. On the other hand, **Low Norm BP** is accompanied by a **maximally increased** PSD of delta-rhythm in C3, T5 and P3 loci as well as its deviation (variability), while in patients with **AH II** such variables are again normal and, as a rule, minimal for the sample. Clusters of patients with intermediate BP levels are also characterized by intermediate levels of the listed variables. Therefore, all 5 clusters are quite clearly demarcated already in the space of the major root.

Additional demarcation of patients with **Norm BP** occurs along the axis of the second root, the bottommost position of which reflects the **maximally suppressed** entropy in O2 locus; PSD of beta-rhythm in T3, T5, T4, F3 and O1 loci; PSD of alpha-rhythm in F7 loci and its deviation; PSD of theta-rhythm in O1 and O2 loci, on the one hand, instead, **normal** and at the same time **maximal** for the sample the index and PSD of alpha-rhythm in Fp2 locus as well as entropy PSD in P3 locus.



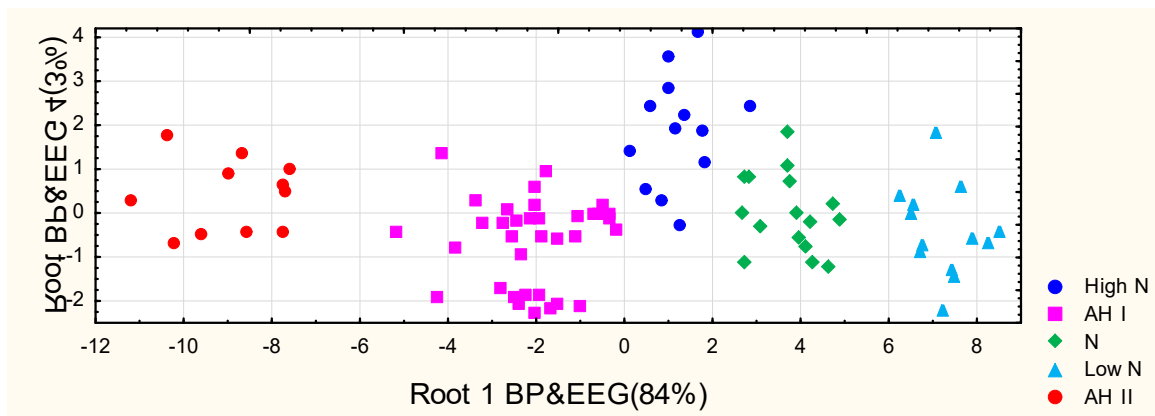


Fig. 2. Scattering of individual values of the discriminant BP&EEG roots of patients of different blood pressure clusters

Patients with **AH II**, in turn, are additionally distinguished from others along the axis of the third root due to a clearly expressed left lateralization of the beta rhythm, as well as **maximally suppressed** entropy in T5 locus and PSD of theta-rhythm in F8 locus.

Finally, along the axis of the fourth root, the polar positions are occupied by clusters of patients with **AH I** and **High N**, which reflects their maximum and minimum levels of theta-rhythm amplitude and its PSD in C4, P4 and Fp1 loci as well as entropy PSD in T3 and C3 loci.

In general, all clusters on the planes of four roots are clearly delineated, which is documented by calculating the Mahalanobis distances (Table 5).

Table 5. Squared Mahalanobis Distances between Blood Pressure Clusters and F-values (df=30,5; for High N-AH I $p < 10^{-4}$; for High N-N $p < 10^{-5}$; for rest $p < 10^{-6}$)

Blood Pressure Clusters	High Norm	AH I	Norm	Low Norm	AH II
High Norm	0	17,5	25,1	47,7	113
AH I	3,60	0	46,3	94,9	55,3
Norm	3,91	11,0	0	40,0	173
Low Norm	6,72	19,5	6,22	0	268
AH II	14,6	10,0	24,4	34,6	0

The same discriminant parameters can be used to identify the belonging of one or another person to one or another cluster (Table 6).

Table 6. Coefficients and Constants for Classification Functions for Blood Pressure Clusters

Blood Pressure Clusters	High N	AH I	Norm	Low N	AH II
Variables currently in the model	p=,148	p=,398	p=,182	p=,148	p=,125
BP systolic, mmHg	10,06	10,92	9,253	8,376	12,83
T3- β PSD, %	-0,493	-0,709	-0,570	-0,558	-0,868
Entropy PSD C3	86,15	101,6	99,44	93,23	118,8
C4- θ PSD, %	7,734	7,381	6,630	7,449	6,454
BP diastolic, mmHg	0,243	0,270	0,481	0,298	-0,228
Deviation- δ , Hz	-17,13	-15,47	-14,58	-6,104	-11,60
Laterality- β , %	0,673	0,675	0,574	0,649	0,613
F7- α PSD, %	0,228	0,187	0,199	0,755	-0,049
P3- δ PSD, %	1,880	1,746	1,581	1,855	1,464

F3-β PSD, %	1,299	1,389	1,161	1,165	1,390
Index-α, %	2,415	2,426	2,150	2,342	2,556
O1-θ PSD, %	4,560	4,771	3,573	3,968	6,362
F8-θ PSD, %	-1,359	-1,051	-0,896	-1,349	-1,348
Amplitude-θ, μV	-2,110	-2,151	-1,475	-2,496	-2,585
Deviation-α, Hz	22,69	22,20	20,48	27,56	16,39
O1-β PSD, %	-1,773	-1,704	-1,426	-1,769	-1,502
T5-β PSD, %	4,189	4,290	3,939	4,480	4,157
T5-δ PSD, %	2,412	2,473	2,504	2,674	2,291
Entropy PSD O2	194,4	187,0	145,6	204,8	194,9
T4-α PSD, %	1,481	1,498	1,476	1,812	1,458
F3-α PSD, %	4,331	4,066	3,646	3,919	4,132
Fp2-α PSD, %	-0,387	-0,229	-0,036	-0,382	-0,404
P4-θ PSD, %	1,176	1,630	0,702	2,221	2,566
Entropy PSD P3	230,9	210,6	214,9	192,1	193,8
C3-δ PSD, %	3,093	3,080	2,734	3,099	3,325
C4-β PSD, %	1,885	1,686	1,587	2,187	1,559
Entropy PSD T3	-170,6	-159,3	-149,7	-175,1	-153,3
O2-θ PSD, %	0,823	0,641	1,465	0,503	-0,223
Entropy PSD T5	-45,45	-44,81	-19,67	-35,70	-63,21
T4-β PSD, %	2,183	2,169	1,978	1,931	2,215
Constants	-1234,9	-1350,8	-1081,8	-1043,8	-1594,7

As you can see, the classification accuracy is absolute (Table 7).

Table 7. Classification matrix

Group	Rows: Observed classifications Columns: Predicted classifications					
	Percent Correct	High N p=, 148	AH I p=, 398	N p=, 182	Low N p=, 148	AH II p=, 125
High N	100	13	0	0	0	0
AH I	100	0	35	0	0	0
N	100	0	0	16	0	0
Low N	100	0	0	0	13	0
AH II	100	0	0	0	0	11
Total	100	13	35	16	13	11

CONCLUSION

Thus, a wide range of blood pressure in Truskavets' spa patients is accompanied by an equally wide range of EEG and HRV parameters and adaptive hormones. Following articles, already prepared for publication, will provide data on metabolic and immune accompaniments of quantitative-qualitative blood pressure clusters. A detailed analysis and discussion will be conducted on the basis of the presented data.

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ACCORDANCE TO ETHICS STANDARDS

Tests in patients are conducted 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 parent of participants the informed consent is got and used all measures for providing of anonymity of participants.

For all authors any conflict of interests is absent.

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