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IMPLEMENTATION OF BIOFEEDBACK IN A CLOSED LOOP OF HEART RATE VARIABILITY AND PACED BREATHING IN PATIENTS WITH ARTERIAL HYPERTENSION

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The effectiveness of biofeedback in a closed loop of heart rate variability (HRV) and paced breathing in patients with arterial hypertension was studied. 61 subjects with arterial hypertension (31 females and 30 males, mean age 56.8 ± 6.2 years) were examined. In accordance with the objective of the study all subjects were divided into 2 groups: 1 - biofeedback group (34 subjects) and 2 - the comparison group (27 subjects). 5 biofeedback sessions were performed in biofeedback group. In the comparison group only two biofeedback sessions were performed - at admission and before discharge from the hospital. Efficacy of biofeedback was evaluated by comparing the values of systolic and diastolic blood pressure (SBP and DBP, respectively), heart rate (HR), HRV indices, indicators of optimality (O), sensitivity (S) and efficiency (E) and BQI index at admission and discharge in both groups of patients. The use of biofeedback in arterial hypertension subjects allowed to achieve better control of heart rate, systolic and diastolic blood pressure and improves HRV indices. The positive dynamics of optimality and the integral BQI values indicated a training effect of regulation systems.

KEY WORDS: arterial hypertension, biofeedback, heart rate variability, paced breathing

ЗАСТОСУВАННЯ БІОЛОГІЧНОГО ЗВОРОТНОГО ЗВ'ЯЗКУ В ЗАМКНУТОМУ КОНТУРІ ВАРІАБЕЛЬНОСТІ СЕРЦЕВОГО РИТМУ І МЕТРОНОМІЗОВАНОГО ДИХАННЯ У ПАЦІЄНТІВ З АРТЕРІАЛЬНОЮ ГІПЕРТЕНЗІЄЮ

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Для вивчення ефективності біологічного зворотного зв'язку в замкнутому контурі варіабельності серцевого ритму (ВСР) і метрономізованого дихання у пацієнтів з артеріальною гіпертензією був обстежений 61 пацієнт з артеріальною гіпертензією (31 жінка і 30 чоловіків, середній вік 56,8 ± 6,2 років). У відповідності з метою дослідження всі випробувані були розділені на 2 групи: 1 - група біофідбеку (34 пацієнтів) та 2 - група порівняння (27 пацієнтів). У групі біофідбеку було проведено 5 сеансів біологічного зворотного зв'язку. У групі порівняння були виконані тільки два сеанси – при надходженні до лікарні та перед випискою. Ефективність біологічного зворотного зв'язку оцінювали шляхом порівняння значень систолічного і діастолічного артеріального тиску, частоти серцевих скорочень, індексів ВСР, показників оптимальності (О), чутливості (S), ефективності (Е) та інтегральним індексом біофідбеку BQI, при надходженні до лікарні та перед випискою в обох групах пацієнтів. Використання біологічного зворотного зв'язку у пацієнтів з артеріальною гіпертензією дозволяє досягти кращого контролю частоти серцевих скорочень, систолічного і діастолічного артеріального тиску та поліпшення показників ВСР. Позитивна динаміка оптимальності та BQI, що спостерігалася, вказує на ефект тренування систем регуляції.

КЛЮЧОВІ СЛОВА: артеріальна гіпертензія, біологічний зворотний зв'язок, варіабельність серцевого ритму, метрономізоване дихання

ПРИМЕНЕНИЕ БИОЛОГИЧЕСКОЙ ОБРАТНОЙ СВЯЗИ В ЗАМКНУТОМ КОНТУРЕ ВАРИАБЕЛЬНОСТИ СЕРДЕЧНОГО РИТМА И МЕТРОНОМИЗИРОВАННОГО ДЫХАНИЯ У ПАЦИЕНТОВ С АРТЕРИАЛЬНОЙ ГИПЕРТЕНЗИЕЙ

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Для изучения эффективность биологической обратной связи в замкнутом контуре вариабельности сердечного ритма (ВСР) и метрономизированного дыхания у больных с артериальной гипертензией был обследован 61 пациент с артериальной гипертензией (31 женщина и 30 мужчин, средний возраст 56,8 ± 6,2 лет). В соответствии с целью исследования все испытуемые были разделены на 2 группы: 1 – группа биофидбека (34 пациентов) и 2 - группа сравнения (27 пациентов). В группе биофидбека было проведено 5 сеансов биологической обратной связи. В группе сравнения были выполнены только два сеанса - при поступлении в больницу и перед выпиской. Эффективность биологической обратной связи оценивали путем сравнения значений систолического и диастолического артериального давления, частоты сердечных сокращений, индексов ВСР, показателей оптимальности (О), чувствительности (S), эффективности (Е) и интегральному индексу биофидбека BQI, при поступлении и выписке в обеих группах пациентов. Использование биологической обратной связи у пациентов с артериальной гипертензией позволило добиться лучшего контроля частоты сердечных сокращений, систолического и диастолического артериального давления и улучшить показатели ВСР. Положительная динамика оптимальности и BQI указывает на эффект тренировки систем регуляции.

КЛЮЧЕВЫЕ СЛОВА: артериальная гипертензия, биологическая обратная связь, вариабельность сердечного ритма, метрономизированное дыхание

INTRODUCTION

Maintaining achieved target blood pressure (BP) levels in patients with arterial hypertension (AH) continues to represent an urgent problem [1].

The desire to minimize the drugs usage in AH treatment boosted searching for non-drug methods. One of them is biofeedback (BFB), its various versions have been used successfully not only in cardiology but also in other branches of medicine [2-5]. A novel approach in BFB is using of heart rate variability (HRV) and the controlled paced breathing (PB) contours [6].

Since the effectiveness of biofeedback with HRV and PB contour in arterial hypertension has not been previously investigated, we decided to perform that research.

The research was conducted under performed under the SRP of the V.N. Karazin Kharkiv National University «Research and development of heart rate variability automatic control system», registration № 0109U000622.

OBJECTIVE

To study the effectiveness of biofeedback in a closed loop of heart rate variability and paced breathing in patients with arterial hypertension.

MATERIALS AND METHODS

61 subjects with arterial hypertension (31 females and 30 males, mean age 56.8 ± 6.2 years) were examined.

Inclusion criteria used were: arterial hypertension I-III stages, 1-3 severiry grades with stable angina pectoris (SAP) I-III functional classes (FC) and chronic heart failure (CHF) I-III functional classes I-IIA stages.

Exclusion criteria were: acute myocardial infarction, SAP FC IV, CHF IV FC, IIB-III stages, acquired valvular defects, implanted pacemakers, atrioventricular conduction disorders, endocrine disorders (diabetes, thyroid diseases), gastric and/or duodenal ulcer in the acute phase.

BP was measured by Korotkov method with Microlife BP AG1- 20 tonometer.

Biofeedback sessions were performed on a computer diagnostic complex «CardioLab 2009» («XAI-Medica») with additional custom module «Biofeedback», including software related audible and visual breathing metronome and dynamic algorithm for determining the current value of HRV indices, changed under PB influence.

HRV parameters were determined in a sliding 1 minute buffer by dynamic spectral decomposition of RR-intervals sequence in monitor ECG recordings using a fast Fourier transform. ECG recordings were performed in the first standard lead with a 1000 Hz signal sampling rate. The calculations were made in real time within the 7 minute session [6]. HRV indices used were: total spectral power (TP) and calculated power of low frequency VLF (V, to 0.05 Hz), mainly associated with humoral regulators and the sympathetic component of the autonomic nervous system; midrange LF (L, 0.05-0.15 Hz), mainly related to the sympathetic and parasympathetic autonomic balance and high frequency HF (H, 0.15-0.40 Hz), mainly related to the parasympathetic autonomic nervous regulation [7]. Further, these parameters have been

converted into two-dimensional coordinate plane with L/H and V/(L+H) axes, corresponding to sympatho-humoral and humoral-vegetative regulation links. As a zero point for these axes the physiological optimum of these balances were selected for each test in accordance with [7], allowing the distance (D) estimation between the current and the optimal values for every subject's HRV indices.

The study algorithm was used to start with a free breath. This step (algorithm initialization) duration was two minutes. On the third minute sympatho-humoral to humoral-vegetative ratio was calculated ratios and representation of paced breath frequency G took place, moving the subjects'maximum of L/H and V/(L+H) current values to the physiological optimum zone, changing a audio-visual metronome rate. The respiration rate G proposed to subject could vary from 6 to 15 breaths per minute.

In accordance with the objective of the study all subjects were divided into 2 groups: 1 - biofeedback group (34 subjects) and 2 - the comparison group (27 subjects). 5 biofeedback sessions were performed in biofeedback group. In the comparison group only two biofeedback sessions were performed - at admission and before discharge from the hospital.

The degree of regulatory systems optimization was assessed in terms of optimality (O), sensitivity (S) and efficiency (E) as a whole and for each of the coordinates of its phase space, as well as the integral indicator " biofeedback quality index» (BQI), covering all changes in biofeedback quality. Methodology for calculating O, S, E and BQI is described in previous publication [6].

All patients received the same treatment in accordance with the Ukrainian Association of Cardiologists Guidelines for arterial hypertension prevention and treatment. [8]. Diuretics, ACE inhibitors, calcium antagonists, beta-blockers were used. Patients with stable angina pectoris were additionally given acetylsalicylic acid and statins, if necessary.

Efficacy of biofeedback was evaluated by comparing the values of systolic and diastolic blood pressure (SBP and DBP, respectively), heart rate (HR), HRV indices, indicators of optimality (O), sensitivity (S) and efficiency (E) and BQI index at admission and discharge in both groups of patients.

The obtained data for all patients was entered into Microsoft Excel, followed by the calculation of mean (M) values and standard deviation (sd). The frequency of the attributes studied, were stated as a percentage, and the average error percentage (Sp) was calculated [9]. The significance of differences between groups on the stages of the study was determined using the U-Mann-Whitney test [10]. The significance of differences between the values of the indices at given stage and before treatment was determined using the T- Wilcoxon test [10].

RESULTS AND DISCUSSION

A clinical characteristic of the subjects in both groups is presented in tab. 1, giving information about most important features of the groups. It can be seen that groups are comparable by clinical features.

Mean SBP, DBP and heart rate values in biofeedback and comparison groups at admission and before discharge are presented in tab. 2. During the same treatment in both groups systemic biofeedback implementation contributed to lower values aforementioned indices.

Values of heart rate variability indices in biofeedback and comparison groups at admission and before discharge are shown in tab. 3. Initially in biofeedback group HRV indices were lower. HRV indices increasing were registered before discharge in both groups, but the biofeedback group had higher values compared to the comparison group.

Optimality, sensitivity and efficiency values measured by the distance from the physiological optimum zone (O^D, S^D and S^D, respectively) in the biofeedback and comparison groups at admission and before discharge are shown in tab. 4. Systematic biofeedback sessions contributed to higher values of optimality due to the effect of the regulation systems «training».

Changes of BQI in biofeedback and comparison groups during the hospital admission are shown in fig. Systematic biofeedback sessions in the biofeedback group contributed its natural approximation to the optimal level, whereas in the control group it remained at the same level.

Table 1

Clinical characteristics of subjects in groups, (n, (% ± *Sp*))

Indices		Group	
		Biofeedback (34)	Comparision (27)
Sex	Males	15, (41.6 ± 8.3)	15, (55.6 ± 9.7)
	Females	19, (52.7 ± 8.4)	12, (44.4 ± 9.7)
Age, years (M ± sd)		54.0 ± 7.6	56.8 ± 6.2
AH stage	I	3, (8.3 ± 4.7)	2, (7.4 ± 5.1)
	II	21, (58.3 ± 8.3)	23, (85.2 ± 6.7)
	III	12, (33.3 ± 8.0)	2, (7.4 ± 5.1)
AH severity grade	Mild	2, (5.5 ± 3.9)	2, (7.4 ± 5.1)
	Moderate	16, (44.4 ± 8.4)	15, (55.6 ± 9.7)
	Severe	9, (25.0 ± 7.3)	10, (37.0 ± 9.5)
SAP FC	I	-	1, (3.7 ± 3.7)
	II	4, (11.1 ± 5.3)	4, (14.8 ± 7.0)
	III	3, (8.3 ± 4.7)	3, (11.1 ± 6.2)
CHF FC	I	14, (38.8 ± 8.2)	16, (59.3 ± 9.6)
	II	2, (5.5 ± 3.9)	5, (18.5 ± 7.6)
	III	-	-
CHF stage	0	11 (30.5 ± 7.8)	3, (11.1 ± 6.2)
	1	11 (30.5 ± 7.8)	14, (51.8 ± 9.8)
	2A	1 (2.8 ± 2.8)	3, (11.1 ± 6.2)
	2B	1 (2.8 ± 2.8)	-

Note: * - P>0.05 between groups.

Table 2

Mean SBP, DBP and heart rate values in biofeedback and comparison groups at admission and at discharge, (M ± sd)

Parameter	Group			
	Biofeedback		Comparision	
	Admission	Discharge	Admission	Discharge
SBP	153.7 ± 17.3*	130.2 ± 11.6*†	158.4 ± 15.7*	133.5 ± 12.7*†
DBP	94.8 ± 13.3*	84.2 ± 8.9*†	94.6 ± 10.3*	85.6 ± 9.9*†
HR	73.2 ± 12.7*	70.1 ± 17.3*†	75.1 ± 9.6*	70.3 ± 8.7*†

Notes: * - p > 0.05 for given index on current stage between groups; † - p > 0.05 for given index in current group comparing to admission levels.

Table 3

Values of heart rate variability indices in biofeedback and comparision groups at admission and before discharge, (M ± sd)

Index	Group			
	Biofeedback		Comparision	
	Admission	Discharge	Admission	Discharge
TP, мс^2	639.9 ± 352.3	2389.7 ± 1160.4†	1003.4 ± 854.5	2067.3 ± 899.7†
VLF, мс^2	257.9 ± 142.1	1117.9 ± 964.6	435.5 ± 370.7	874.3 ± 541.5
LF, мс^2	283.8 ± 363.0	700.0 ± 406.7	290.9 ± 308.2	554.0 ± 327.3
HF, мс^2	189.8 ± 162.1	441.9 ± 203.9	250.1 ± 249.4	567.0 ± 445.6
LF/HF	1.71 ± 1.77	1.57 ± 0.69	2.17 ± 1.86	1.60 ± 1.82

Note: † - p> 0.05 for given index in current group comparing to admission levels.

Table 4

Average O^D, S^D and S^D values in biofeedback and comparison groups at admission and before discharge, (M ± sd)

Index	Group			
	Biofeedback		Comparision	
	Admission	Discharge	Admission	Discharge
O^D	-3.2 ± 4.4*	-6.2 ± 6.9*†	-5.8 ± 7.7*	-6.1 ± 8.1*†
S^D	1.0 ± 0.5*	1.0 ± 0.4*†	0.9 ± 0.5*	0.9 ± 0.5*†
E^D	0.2 ± 0.3*	0.06 ± 0.1*†	0.2 ± 0.2*	0.2 ± 0.3*†

Notes: * - p > 0.05 for given index on current stage between groups; † - p > 0.05 for given index in current group comparing to admission levels.

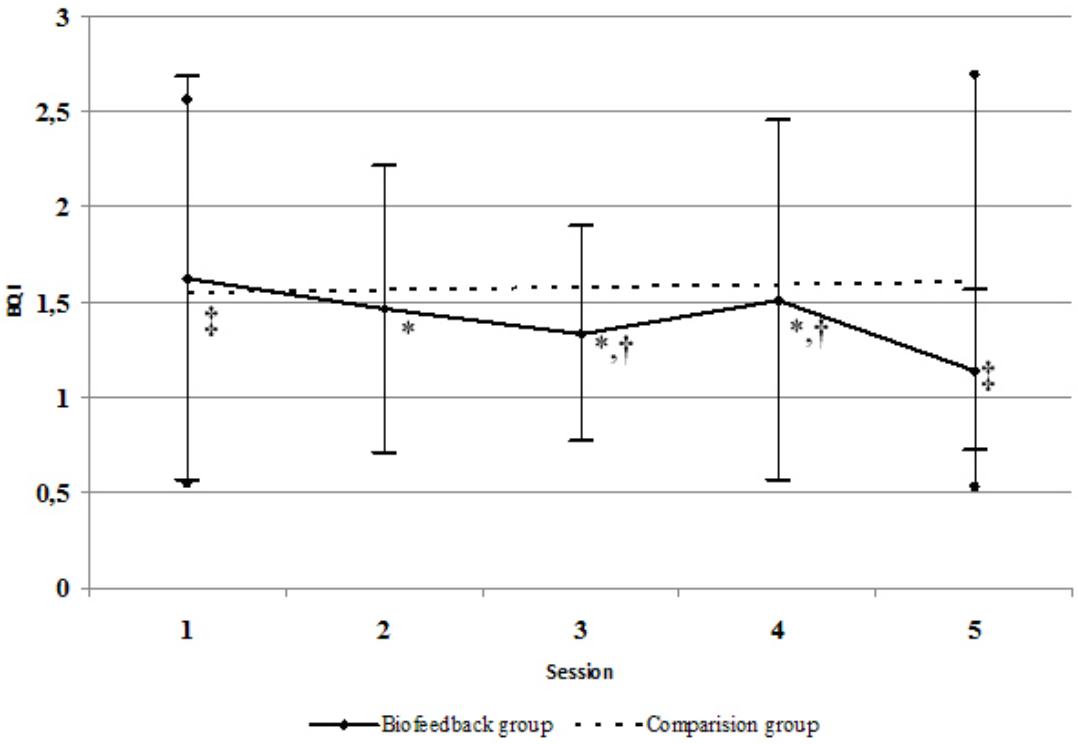

Fig. BQI changes during hospital admission in biofeedback and comparison groups

Note: * - p > 0.05 on current stage comparing to admission values;
† - p > 0.05 on current stage comparing to previous session value;
‡ - p > 0.05 between biofeedback and comparison groups on current session.

The findings suggest that the biofeedback with HRV and PB contour in arterial hypertension subjects not only improves the quality of its control, but also helps to optimize the regulatory systems that are crucial in the mechanisms of the disease [11, 12]. The similar results have been obtained; where it was shown that HRV biofeedback decreases blood pressure in prehypertensive subjects [13] and that the breathing pattern of 5.5 breaths per minute with an inhale/exhale ratio of 5/5 achieved greater HRV than the other breathing patterns [14]. The major difference is that in our study breath rate could be automatically shifted from 6 to 15 breaths per minute «on fly» depending on HRV indices, while almost in all biofeedback studies with paced breathing the breath rate is limited to 6 per minute.

CONCLUSIONS

1) The use of biofeedback with HRV and PB contour in arterial hypertension subjects allows achieving better control of heart rate, systolic and diastolic blood pressure and improves HRV indices.

2) The positive dynamics of optimality and the integral BQI values observed during study demonstrated a high effectiveness of bio-feedback in a closed loop of heart rate variability and paced breathing in patients with arterial hypertension.

PROSPECTS FOR FUTURE STUDIES

The demonstrated effectiveness of proposed new biofeedback in a closed loop of heart rate variability and paced breathing have shown that it can be used in health care practices in hospitals and out-patient clinics.

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