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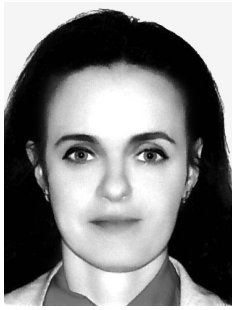

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Condition of the pro-/antioxidant system and heart rate variability in subjects from various functional groups

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Oxidative stress (OS) is a basic pathogenetic mechanism of many diseases. Its depth is usually assessed by the parameters of pro-/antioxidant balance which not necessarily reflect the intensity of redox reactions. Therefore, the search of the integrative indexes reflecting the condition of the aerobic metabolism remains to be an important task. Noninvasive study of heart rate variability (HRV) is increasingly recognized not only as the tool for assessment of the regulatory systems activity but also pro-/antioxidant balance and organism's stress resistance.

The aim of this work was to study the condition of aerobic metabolism by the parameters of pro-/antioxidant system and HRV in patients from various functional groups.

Materials and methods. Thirty six patients with type 2 diabetes mellitus (DM), 40 patients with duodenal peptic ulcer disease (PUD), 36 athletes and 40 healthy volunteers (control group) were enrolled into the study. Time and frequency domain indexes of HRV were assessed in short ECG records (5 min in supine position, 6 min while standing — orthostatic test) using a computer electrocardiograph «VNS-Micro» and Neurosoft software. The parameters of pro-/antioxidant system, namely, activities of catalase and superoxide dismutase (SOD), levels of thiobarbituric acid reactive species (TBARS), hydroperoxides, low density lipoproteins (β—LP), oxidatively modified proteins (OMP), and middle mass molecules (MMM) were determined in blood spectrophotometrically.

Results and discussion. Signs of OS were demonstrated in subjects from all functional groups, with the most profound changes in DM subjects and the least prominent — in athletes. In type 2 DM patients elevation of oxidation destruction products and increase in the activity of antioxidant enzymes were accompanied by marked lowering of HRV with predominance of VLF band in the spectrum structure. Similar changes of the pro-antioxidant balance in athletes were associated with markedly higher HRV indexes and high activity of the autonomic components (LF, HF) in the spectral structure. In PUD patients signs of OS were also demonstrated but their depth was much less prominent. HRV decrease especially during orthostatic test was noted in this group.

Conclusions. This study demonstrated that HRV reflects the functional metabolic reserve and signs of OS in subjects from various functional groups. Thus, it is a perspective tool for the assessment and monitoring of the pro-/antioxidant balance and adaptive reserve in patients with OS associated disorders.

Key words: heart rate variability, oxidative stress, pro-/antioxidant system, functional metabolic reserve, diabetes mellitus, athletes, peptic ulcer disease.

At the present stage of development of the biomedical science oxidative stress (OS) is considered to be one of the main pathogenetic mechanisms involved in the variety of chronic illnesses including diabetes, peptic ulcer, cardiovascular, pulmonary disorders, etc [15]. The excessive physical and emotional load commonly found in athletes is also associated with signs of OS [12, 22]. In general, constant exposure to the multiple stressors lowers an adaptive potential of the modern man, which at the metabolic level manifests as the pro-/antioxidant imbalance. It further leads to the impaired physiological and biochemical signaling, strains regulatory systems of organisms and causes disorders of main homeostatic contant.

Biochemical tests used for the assessment of the levels of oxidative destruction products or activity of common antioxidant enzymes are not informative about the depth of OS. This statement stems from the understanding of OS as the condition caused not only by excessive production of free radicals, but also by their untimely and inappropriate utilization by the components of antioxidant defense [27, 28]. Therefore, persistence of OS is attributed primarily to the low intensity of the redox processes and the depth of OS is not similar in patients with different disorders (from various functional groups). The efficient management strategy of OS-associated conditions would require close monitoring of the functional-metabolic potential of an organism that can be achieved with the study of heart rate variability (HRV). HRV is a noninvasive diagnostic tool and its indexes reflect the activity of main regulatory systems, their potency, hierarchical

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balance, resistance and reactivity as well [14, 17, 18]. Modern data allow to speculate that heart rhythm is affected not only by neurohumoral and autonomic regulations but also it reflects the condition of the aerobic metabolism and adaptive potential of an organism [2, 26, 29].

The aim of present research was to study the condition of aerobic metabolism by the parameters of pro-/antioxidant balance and HRV in subjects from various functional groups.

Materials and methods

Study design and populations

Thirty six patients with verified type 2 diabetes mellitus (DM) (aged 57 ± 7 years, male 20 (55.6 %), female 16 (44.4 %)) were enrolled into the study. Body mass index ranged from 26 to 30 kg/m^2 in 22 (61.1 %) subjects and from 30 to 35 kg/m^2 in 14 (38.9 %). The disease duration ranged from one to ten years: 18 (50 %) subjects had one to five years history of diabetes and 18 (50 %) were ill from six to ten years. All patients were diagnosed with moderately severe diabetes (by European Diabetes Policy Group, 1998) with fasting glucose 6.7 ± 1.4 mmol/L and Hb_{A1c} 7.76 ± 0.83 %. The group with duodenal peptic ulcer diseases (DPUD) consisted of 40 subjects (mean age 32.1 ± 1.7 years, 24 males, 16 females) with endoscopically proven peptic ulcer and positive *H. pylori* testing. The majority (80 %) of patients had the disease duration up to 5 years. The athletes group consisted of 36 national and regional level competitive male athletes (mean age 26.1 ± 4.2 years). All of them were specialized in running or triathlon training. Athletes were not participating in any competitions, had no injuries, other diseases or deviations of their usual regimen one week before participation in the study. Healthy volunteers (n = 40, mean age 29.7 ± 3.5 years, 25 males and 15 females, body mass index 23.5 ± 3.1 kg/m^2) without any complaints or other registered health problems served as a control group.

All investigations and blood sampling were performed in the morning hours between 9 a.m. and 11 a.m. before meal. Patients and healthy volunteers were asked to restrain from smoking and drinking alcohol at the days when blood collections and other studies were performed. The design of the study was approved by the local Ethics Committee at Lviv National Medical University and informed consent was obtained from all patients and healthy volunteers.

Spectrophotometric studies

The parameters of pro-/antioxidant system were assessed in blood as described previously [26, 29]. Spectrophotometric measurements of the catalase and superoxide dismutase (SOD) activities were determined together with detection of thiobarbituric acid reactive substrates (TBARS), hydroperoxides, low density lipoproteins (β-LP), oxidatively modified proteins (OMP), and middle mass molecules (MMM) levels.

Study of heart rate variability

The short-time records of ECG were performed using a computer electrocardiograph «VNS-Micro» (Neurosoft®, Russia). During quite wakefulness after 20 min of rest, patients were asked to stay supine quietly for 5 min for stationary condition HRV recording (clinostasis); afterwards they were asked to stand up rapidly and remained in the standing position for 6 min (orthostatic test). RR intervals were determined with a sampling frequency of 2 kHz and were analyzed with «Poly-Spectrum» (Neurosoft®, Russia) software designed according to HRV standards [11]. The time-domain indices — standard deviation of normal RR intervals (SDNN), square root of mean squared differences of successive RR interval (RMSSD), and percentage of differences between adjacent normal RR intervals exceeding 50 milliseconds (pNN50) were determined. Power spectral analysis was performed sequentially with a fast Fourier transformation. The following frequency-domain variables were studied: total power (TP, 0.01 to 0.4 Hz), high frequency power (HF, 0.15 to 0.4 Hz, reflects activity of parasympathetic nervous system), low frequency power (LF, 0.04 to 0.15 Hz, reflects predominantly activity of sympathetic nervous system), and very low frequency power (VLF, 0.01 to 0.04 Hz, reflects activity of neurohumoral regulation). Further, $K_{30/15}$— the ratio of maximal to minimal heart rate during the first 30 heart cycles of orthostatic test was calculated.

Statistical analysis

All data were processed using the statistical package Statistica 6.0. Normal distribution of the obtained data was confirmed with Shapiro–Wilk's W-test. Normally distributed data are presented as means ± standard deviation (M ± m). The t-test for independent variables was used to compare means between groups. Nonparametric Mann–Whitney U-test was used to compare HRV parameters.

Results and discussion

All studied groups were demonstrated with the signs of OS, which, however, were associated with either low or high HRV. Because of the marked individual variation of HRV indexes especially in athletes and type 2 DM patients the subjects from these groups were subdivided according to the TP value, which reflects total spectral power of the heart rate and is strongly associated with the stress resistance and adaptive potential of an organism [7, 9, 13, 14, 18]. Among diabetic patients two groups were formed: very low resistance (VLR) group 1 (n = 18) included those with the dramatically low HRV (TP ≤ 400 ms^2), while low resistance (LR) group 2

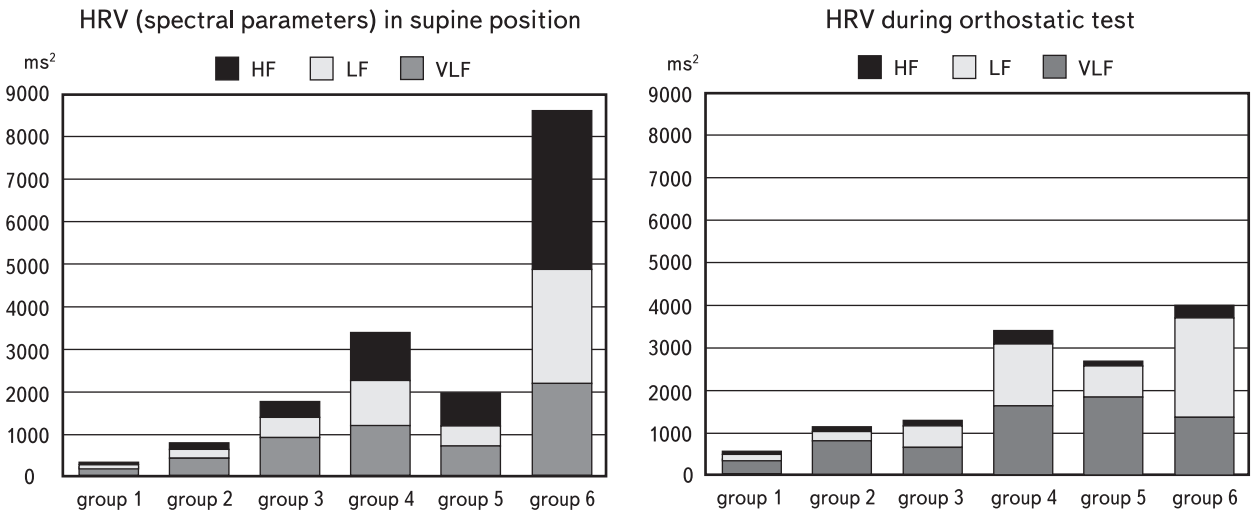

Figure 1. **Changes in the spectral indexes of HRV in subjects from different functional groups**

Note. Changes of the most HRV indexes comparing to the control group 4 are significant, except of VLF in group 3 in supine position and TP, VLF, HF in group 6 and VLF group 5 during orthostasis. Group 1 — patient with type 2 diabetes mellitus (DM), duration of disease > 5 years, VRL — very low resistance; group 2 — patients with type 2 DM, duration of disease < 5 years, LR — low resistance; group 3 – patients with duodenal peptic ulcer disease (DPUD), disease duration < 10 years; group 4 — healthy volunteers, control; group 5 — medial resistance (MR) athletes; group 6 — high resistance (HR) athletes.

(n = 18) comprised of the individuals with slightly higher HRV (TP > 400 ms^2). The medial resistance (MR) group 5 (n = 18) included athletes with TP below 5000 ms^2 while those with higher TP formed the high resistance (HR) group 6 (n = 18). In general, the distribution of the studied subjects according to TP is shown at the Figure 1.

Signs of OS were demonstrated in the subjects from different groups, however, they were much less prominent than HRV changes in these groups. Moreover, the levels of OMP, activities of catalase and SOD in patients with type 2 DM and the lowest HRV and athletes with the highest HRV were similar Table 2. The main differences between these two polar groups were demonstrated by the levels of the lipid oxidative destruction (TBARS and hydroperoxides), β-LP, MMM_{280} and to the some extend MMM_{254}, which points to the relations between low HRV and depth of OS.

Athletes from the HR group 6 had significantly (4—5 fold) higher HRV predominantly on account of the autonomic upregulation (HF and LF bands) comparing to the group 5 MR athletes. Importantly, that VLF which reflects activity of the neurohumoral mechanisms in the spectral structure was reduced in athletes with higher HRV (group 6). Such beneficial HRV pattern in supine position was not maintained during orthostatic test, which was accompanied by the marked decrease in SDNN, RMSSD, pNN50, TP and HF and worsening of the reactivity of the physiological systems (low $K_{30/15}$ index) (Table 1, Figure 1). These changes and particularly decrease in TP with the ratio $TP_{ortho}/TP_{supine} \leq 0.5$ can be suggestive about the low intensity of the recovery processes and strain of the adaptive mechanisms in athletes from HR group 6. At the same time, in athletes from group 5, who had lower HRV comparing to control group 4 in supine position, increase in HRV during orthostatic test was found. Notably, it occurred predominantly on account of the VLF component pointing to the reduced potency of the functional metabolic reserve and strain of the central regulatory mechanisms. Low HRV in group 5 competitive athletes can reflect insufficient recovery and, thus, a correction of their training regimen is needed [10].

Signs of OS in athletes were demonstrated by elevated levels of OMP, MMM and changes in the activities of catalase and SOD (Table 2). Namely, in group 6 activities of catalase and SOD were the highest, while the levels of TBARS and β-LP were below normal. Some increase in MMM_{254} and marked elevation of MMM_{280} were accompanied by a significant rise in both fractions of OMP in both sport groups. These findings may point to the importance of OMP as the sensitive marker of OS (Table 2). In general, the study of aerobic metabolism in athletes from group 5 demonstrated pronounced signs of OS (by lower activity of SOD and higher levels of TBARS, β-LP and OMP) comparing to the group 6 athletes. Such changes were accompanied by marked lowering of HRV. To the contrary, in HR group 6 more efficient mechanisms of OS compensation possibly provided by the higher energy and membrane potential could serve as the basis for the HRV increase.

Table 1

Time domain parameters and K30/15 in patients from various functional groups, M ± m

Index	DM type 2, Group 1 (VLR)#	DM type 2, Group 2 (LR)	DPUD, Group 3	Healthy volunteers, Group 4	Athletes, Group 5 (MR)	Athletes, Group 6 (HR)
	n = 18	n = 18	n = 40	n = 40	n = 18	n = 18
			Supine position			
HR, bpm$	72.2 ± 1.7	70.2 ± 1.5	76.3 ± 1.2*	69.0 ± 1.7	—	—
SDNN, ms	16.5 ± 0.6*	26.0 ± 0.6*	36.3 ± 1.6*	53.3 ± 3.1	45.3 ± 2.2*	93.3 ± 6.1*
RMSSD, ms	10.7 ± 0.6*	15.8 ± 1.5*	23.6 ± 1.4*	44.4 ± 3.6	44.17 ± 4.5	98.8 ± 6.8*
pNN50, %	0.1 ± 0.05	1.51 ± 0.7*	5.5 ± 1.1*	23.2 ± 2.9	20.15 ±2.5	49.9 ± 4.2*
			Orthostatic test			
HR, bpm	82.8 ± 2.2	78.0 ± 1.5*	94.5 ± 1.5*	85.6 ± 1.6	—	—
SDNN, ms	22,5 ± 1.9*	32.0 ± 2.1*	31.2 ± 1.3*	59.5 ± 9.4	53.6 ± 3.4	65.2 ± 3.6
RMSSD, ms	11.7 ± 2.2*	13.5 ± 1.0*	13.5 ± 1.1*	31.2 ± 9.9	18.5 ± 1.3*	30.0 ± 1.9
pNN50, %	0.9 ± 0.3*	0.6 ± 0.2*	0.6 ± 0.1*	3.8 ± 0.6	2.05 ± 0.6*	7.96 ± 1.1*
$K_{30/15}$	1.13 ± 0.02*	1.15 ± 0.03*	1.25 ± 0.02*	1.38 ± 0.03	1.49 ± 0.03*	1.17 ± 0.04*

Note. * — difference between groups significant ($p < 0.05$) comparing to the volunteers group 4.
$ HR — heart rate, bpm —beats per minute; SDNN — standard deviation of normal RR intervals, ms; RMSSD — square root of mean squared differences of successive RR interval, ms; pNN50 — percentage of differences between adjacent normal RR intervals exceeding 50 milliseconds.
# here and on group 1 — patient with type 2 diabetes mellitus (DM), duration of disease > 5 years, VRL — very low resistance; group 2 — patients with type 2 DM, duration of disease < 5 years, LR — low resistance; group 3 — patients with duodenal peptic ulcer disease (DPUD), disease duration < 10 years; group 4 — healthy volunteers, control; group 5 — medial resistance (MR) athletes; group 6 — high resistance (HR) athletes.

Additionally, persisting exercise-induced OS in athletes can adversely affect sport performance [6, 16, 20, 22, 24] and study of HRV has a great potential in evaluation and monitoring of athletes in this regard.

Study of HRV in DPUD group 3 (Table 1, Figure 1) showed marked decrease in the main time (SDNN, RMSSD, pNN50) and frequency (TP, LF та HF) domain indexes comparing to the healthy subjects from group 4. Absolute values for the VLF band did not differ significantly from group 4, but, when take into account high VLF percentage in the HRV spectrum structure, strain of the central regulatory mechanisms

Table 2

Parameters of aerobic metabolism in patients from various functional groups, M ± m

Parameters	DM type 2, Group 1 (VLR) #	DM type 2, Group 2 (LR)	DPUD, Group 3	Healthy volunteers, Group 4	Athletes, Group 5 (MR)	Athletes, Group 6 (HR)
	n =1 8	n = 18	n = 39	n = 40	n = 18	n = 18
Catalase, μM H_2O_2/ml·h	0.169 ± 0.01*	0.163 ± 0.01*	0.131 ± 0.01	0.136 ± 0.01	0.176 ± 0.01*	0.183 ± 0.01*
SOD, % inhibition	12.6 ± 1.1	19.4 ± 1.0*	11.4 ± 1.4	12.8 ± 1.1	11.3 ± 1.3	20.6 ± 1.9*
TBARS, μM	109.5 ± 2.4*	114.7 ± 3.9*	71.5 ± 1.5	71.9 ± 2.2	78.1 ± 1.7*	60.9 ± 1.4*
β-lipoproteins, CU/ml	118.6 ± 4.1*	114.9 ± 5.0*	54.3 ± 1.2	51.5 ± 1.5	66.6 ± 3.8*	47.6 ± 2.6
Hydroperoxides, 234 nm, CU	4.1 ± 0.1*	2.7 ± 0.1*	2.4 ± 0.03*	1.5 ± 0.1	1.8 ± 0.04*	1.6 ± 0.03
MMM, 254 nm, CU/ml	236.3 ± 6.8	220.3 ± 5.4*	182.6 ± 2.0*	241.4 ± 8.7	250.0 ± 3.2	271.0 ± 14.6*
MMM, 280 nm, CU/ml	245.4 ± 6.4*	248.9 ± 8.8*	230.5 ± 3.9*	270.5 ± 12.0	324.2 ± 10.7*	351.3 ± 28.2*
MMM, 254/280	1.1 ± 0.1*	1.1 ± 0.1*	0.8 ± 0.01*	0.9 ± 0.03	0.8 ± 0.01*	0.8 ± 0.03*
OMP, 370 nm, CU/ml	6.2 ± 0.2*	7.1 ± 0.3*	5.2 ± 0.2	5.0 ± 0.2	9.7 ± 0.3*	9.1 ± 0.2*
OMP, 430 nm, CU/ml	2.8 ± 0.2*	4.3 ± 0.3*	2.2 ± 0.1*	1.6 ± 0.1	4.3 ± 0.3*	4.0 ± 0.2*
OMP, 370/430	2.6 ± 0.1*	1.8 ± 0.1*	2.3 ± 0.1*	3.2 ± 0.2	2.4 ± 0.1*	2.3 ±0.1*

Note. * — difference between groups significant ($p < 0.05$) comparing to the volunteers group 4. CU — conventional units;
MMM — middle mass molecules; OMP — oxidatively modified proteins; SOD — superoxide dismutase; TBARS — thiobarbituric acid reactive species.

can be easily noted. Interestingly, there was no anticipated vagal hyperactivity in DPUD patients but to the contrary HF band was reduced and LF/HF ratio was elevated. Orthostatic test in this group also demonstrated strain of the central regulatory mechanisms and failure of the adaptive mechanisms shown by lowering of TP, SDNN, RMSSD, pNN50, $K_{30/15}$, HF band and progressing autonomic imbalance (by LF/HF ratio). Changes of HRV in DPUD are in accordance with the modern statement about the significant role of OS in the pathogenesis of this illness [1, 5, 15, 19, 25]. Indeed, impaired pro-/antioxidant balance was noted by markedly elevated level of hydroperoxides, which are primary products of lipid peroxidation. At the same time normal levels of TBARS (secondary lipid peroxidation products) pointed rather to insufficient utilization than to excessive production of these oxidative destruction products. Taking into the account the fact that hydroperoxides have high destructive potential towards macromolecules their excessive accumulation is an important signs of OS. Further presence of OS in DPUD was confirmed by significantly elevated levels of OMP_{430}. However, normal level of OMP_{370} was accompanied by decrease in both fractions of MMM in these patients. Because MMM include neuropeptides, inflammatory mediators, signal molecules, heat shock proteins, transcriptional factors that induce genes of the antioxidant defense (e.g. ARE-antioxidant response elements), depletion of these regulatory molecules may contribute to the MMM decrease. Such findings agree with the current concept of OS, according to which accumulation of the oxidative destruction products results from the low intensity of redox reaction [21, 27].

The most prominent signs of OS were observed in patients with type 2 DM as demonstrated by the significantly increased levels of lipid and protein oxidative destruction products. The division of these patients into two resistance groups allowed to identify subjects with the lowest adaptive potential and OS resistance characterized by critically low spectral power (TP < 400 ms^2) and almost rigid rhythmogram (group 1). The highest activity of the VLF band (59.9 %) in the spectral structure of these individuals showed strain of the central regulatory mechanisms. Simultaneously, sympathetic predominance by LF/HF ratio was demonstrated. Orthostatic test in VLR group 1 was characterized by almost two-fold increase in TP, HF, and LF bands. Although group 2 DM patients were observed with the similar spectrum structure both in supine position and during orthostasis HRV indexes in this group were significantly higher. The reaction to the orthostatic test which mimics exertion in this LR group showed mild increases in TP (by 260 ms^2) and LF (by 71 ms^2), which were obviously not sufficient to support an adequate reaction of the heart rate (Figure 1). The results of our study are in agreement with the literature data about the presence of deep OS and dramatic decrease in HRV in type 2 DM subjects [3, 4, 8, 23, 30]. Accumulation of oxidative destruction products and cell and tissue hypoxia in these patients may exert a great impact on the cardiorespiratory function and markedly lower an adaptive potential.

Conclusions

To sum up, the noninvasive study of HRV can be used for estimation and monitoring of the functional metabolic reserve in subjects with OS associated disorders. Low HRV, which is associated with poor functional metabolic reserve and severe OS can be defined as TP < 1000 ms^2, SDNN < 30 ms^2, RMSSD < 20 ms^2, pNN50 < 5—7 %, high percentage of VLF (> 40 %) and low percentage of HF (< 30 %) in spectral structure in supine position and low ratio of TP during orthostasis to TP in supine position (TP_{ortho}/TP_{supine} < 0.5). Conversely, potent functional metabolic reserve and improved stress resistance, even in subjects with the signs of OS such as athletes, are reflected by high HRV. In that case TP > 3000 ms^2, SDNN > 40 ms^2, RMSSD > 25 ms^2, pNN50 > 15—20 %, low percentage of VLF (< 20 %), high percentage of HF (> 40 %) in the supine position with an increase in TP_{ortho}/TP_{supine} ratio up to 1.0—2.5 are observed. Thus, HRV shows an outstanding diagnostic potential for the assessment of the activity and efficacy of the aerobic metabolism. As it was demonstrated by the comparison of subjects from various functional groups deepening of the OS signs was accompanied by progressive lowering of HRV. Further studies in this regard are needed.

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Стан системи про-/антиоксиданти та варіабельності серцевого ритму в осіб із різних функціональних груп

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Окисний стрес (ОС) є важливим патогенетичним механізмом виникнення багатьох захворювань. Його глибина звичайно оцінюється за параметрами про-/ антиоксидантного балансу, що не достатньо характеризує інтенсивність окисно-відновних процесів. Пошук інтегративних параметрів, які б адекватно відображали стан аеробного метаболізму, залишається дуже важливим завданням. На сьогоднішній день неінвазивне дослідження варіабельності серцевого ритму (ВСР) все частіше розцінюється як метод оцінки не лише функціональної активності регуляторних систем, а й стану системи про-/антиоксиданти та стресостійкості організму.

Метою роботи було вивчити стан аеробного метаболізму за параметрами системи про-/антиоксиданти та ВСР у пацієнтів із різних функціональних груп.

Матеріали та методи. У дослідження були включені 36 хворих на цукровий діабет (ЦД) 2 типу, 40 хворих із виразковою хворобою дванадцятипалої кишки (ВХДПК), 36 спортсменів та 40 здорових волонтерів (контрольна група). Часові та спектральні показники ВСР оцінювали у коротких записах ЕКГ (5 хв у положенні лежачи, 6 хв стоячи – ортостатична проба) за допомогою приладу ВНС-мікро® та програмного забезпечення Нейрософт® (РФ). Глибину ОС оцінювали спектрофотометрично за рівнями продуктів, що реагують із тіобарбітуровою кислотою (ТБКАП), гідропероксидів, β-ліпопротеїнів, середньомолекулярних пептидів, окисно-модифікованих білків та активністю супероксиддисмутази та каталази в крові.

Результати та обговорення. Ознаки ОС були виявлені в осіб з усіх функціональних груп, причому найбільш глибокі прояви ОС спостерігались у осіб із ЦД, а найменш виражені зміни — у спортсменів. У хворих на ЦД 2 типу збільшення рівнів продуктів окисної деструкції та підвищення активності антиоксидантних ферментів супроводжувалося значним зниженням ВСР із переважанням у структурі спектра VLF коливань. В той же час схожі зміни про-/антиоксидантного балансу в спортсменів асоціювалися зі значно вищими параметрами ВСР та високою активністю автономних компонент (LF, HF) у структурі спектра. У хворих на ВХДПК також було виявлено ознаки ОС, однак їх глибина була значно менш виразною, що також супроводжувалось деяким зниженням параметрів ВСР, особливо в ортостатичній пробі.

Висновки. Дослідження ВСР у пацієнтів різних функціональних груп переконливо демонструють, що низька ВСР асоціюється зі зниженим функціонально-метаболічним резервом і персистенцією ОС. ВСР є перспективним методом оцінки та моніторингу дисбалансу в системі про-/антиоксиданти та адаптаційного резерву в осіб із ОС-асоційованими станами.

Ключові слова: варіабельність серцевого ритму, окисний стрес, система про-/антиоксиданти, функціонально-метаболічний резерв, цукровий діабет, атлети, виразкова хвороба.

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Состояние системы про-/антиоксиданты и вариабельности сердечного ритма у индивидов различных функциональных групп

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Окислительный стресс (ОС) является важным патогенетическим механизмом возникновения многих заболеваний. Его глубина обычно оценивается по показателям системы про-/антиоксиданты, которые не достаточно характеризируют интенсивность окислительно-восстановительных процессов. Поэтому поиск интегративных параметров, по изменениям которых можно было бы адекватно оценить состояние аэробного метаболизма, остается очень актуальным. На сегодняшний день неинвазивное исследование вариабельности сердечного ритма (ВСР) все чаще рассматривается как метод оценки не только активности регуляторных систем, но и состояния системы про-/антиоксиданты и стрессоустойчивости организма.

Целью работы было изучить состояние аэробного метаболизма по параметрам системы про-/антиоксиданты и ВСР у пациентов различных функциональных групп.

Материалы и методы. В исследование были включены 36 больных сахарным диабетом (СД) 2 типа, 40 больных язвенной болезнью двенадцатиперстной кишки (ЯБДПК), 36 спортсменов и 40 здоровых волонтеров (контрольная группа). Временный и спектральный показатели ВСР анализировали в коротких записях ЭКГ (5 мин лежа, 6 мин стоя – ортостатическая проба) с помощью прибора ВНС-микро® и программного обеспечения Нейрософт® (РФ). Глубина ОС оценивалась спектрофотометрически по уровням продуктов, которые реагируют с тиобарбитуровой кислотой (ТБКАП), гидропероксидов, β-липопротеидов, среднемолекулярных пептидов, окислительно модифицированных белков и активностями супероксиддисмутазы и каталазы в крови.

Результаты и обсуждение. Проявления ОС были обнаружены у испытуемых различных функциональных групп, причем наиболее глубокие проявления ОС были продемонстрированы у больных СД, а изменения наименьшей

глубины — у атлетов. У больных СД 2 типа увеличение продуктов окислительной деструкции и повышение активности антиоксидантных ферментов сопровождалось значительным уменьшением ВСР и преобладанием VLF-колебаний в структуре спектра. В то же время похожие изменения про-/антиоксидантного баланса у спортсменов ассоциировались с высокой ВСР и повышением активности автономных регуляторных компонент (LF, HF) в структуре спектра. У больных ЯБДПК также были обнаружены проявления ОС, однако их выраженность была меньше, чем у больных СД, и, соответственно, сопровождалась некоторым снижением ВСР, особенно в ортостатической пробе.

Выводы. Исследования ВСР у пациентов различных функциональных групп убедительно показывают, что низкая ВСР ассоциируется со снижением функционально-метаболического резерва и персистенцией проявлений ОС. ВСР является перспективным методом оценки и мониторинга глубины про-/антиоксидантного дисбаланса и эффективности адаптационного резерва у испытуемых с ОС-ассоциированными состояниями.

Ключевые слова: вариабельность сердечного ритма, окислительный стресс, система про-/антиоксиданты, функционально-метаболический резерв, сахарный диабет, язвенная болезнь, спортсмены.