Chapter 26

Effectiveness Application of the Analysis of Arterial Pulsations Registered during Blood Pressure Measurement Using the Oranta-AO Information System in Psychophysiology

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Abstract

Introduction: Post-traumatic stress disorders associated with the situation in Ukraine, rapid societal automation and informatization have demanded the development of new, accessible, and highly informative methods for diagnosis, monitoring, prediction, and patient state correction.
Objective: To study the level of heart and brain rhythm activity at rest and their dynamics during adaptation to changing external conditions.
Materials and Methods: A total of 720 individuals of both genders, various ages, and health statuses were examined using the arterial oscillography method. Arterial oscillograms (AOG) were recorded during the measurement of arterial pressure at rest and after the influence of different factors (physical, thermal, multimedia, etc.). AOG analysis was conducted using temporal and spectral methods developed by the authors of the study.
Results: The research has shown that in cases of depressive disorders, there is an increase in the activity of the sympathetic-adrenal system, which is manifested by a disruption in the functional ability of all levels of hemodynamic regulation. Some changes in brain rhythm activity have been observed under the influence of various factors. Exposure to natural water sounds resulted in the suppression of sympathetic activity and activation of the parasympathetic branch of the autonomic nervous system, leading to improved cardiovascular functional capacity.
Conclusions: The application of the proposed AOG analysis methods has allowed us to come to the following conclusions. Depressive disorders serve as a basis for the development of specific cardiovascular problems, and early detection of predispositions to

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these issues is crucial. The beneficial impact of the “Water” video composition can be used as a psychomodulating factor for restoring organismal homeostasis.

Keywords: arterial pressure measurement, psychophysiology, arterial oscillography, functional capabilities, heart, vessels, autonomic nervous system, Information system Oranta-AO

1. Introduction

Depression is one of the most common diseases worldwide, and according to the World Health Organization, about 500 million people are depressed. This situation is further complicated by the fact that this ailment affects primarily people of working age, which places a heavy burden on society and poses a significant issue in terms of relationships (the maximum number of cases of this condition is within the 20-39 year age range). The ongoing combat operations in Ukraine exacerbate this issue. Post-traumatic stress syndrome has become a significant concern for the state, healthcare professionals, patients, and their family members (Bucher et al., 1997).

In Ukraine, cardiovascular diseases have almost doubled in recent decades and today confidently occupy a leading position in the structure of overall mortality in Ukraine and remain one of the highest rates in Europe and the world. Every fifth patient with coronary heart disease and heart failure is diagnosed with depression, which statistically doubles mortality, disability, and reduces the patient's quality of life, and this dependence correlates with the severity of depression itself. Depression affects the autonomic tone, changing the balance of autonomic influences and the adaptive capacity of the myocardium. It was found that the severity of depressive symptoms is associated with the intensity of vagal activity. The above indicates the need to improve the system of prevention, early detection, and assistance to persons with depressive disorders and emphasizes the relevance of this problem.

The information capabilities of the blood pressure measurement procedure are endless. From 2010 to 2023, the authors of the study went from an idea to the development and implementation of an information system for conducting scientific research aimed at studying, substantiating and implementing into practice methods for analyzing arterial pulsations recorded during blood pressure measurement in 2000 patients (more than 4000 AO).

In 2021, clinical trials were conducted, and the Oranta-AO information system was certified as a medical device for implementation in various fields of medicine, rehabilitation, sports, education, in a telediagnostic information system and tele-rehabilitation with feedback.

The results of the research are reflected in publications (Selskyy et al., 2018; Romaniv et al., 2022; Martseniuk et al., 2007, 2018, 2020, 2021, 2022; Mintser et al., 2020 & Vakulenko et al., 2015, 2017 - 2022) and in sections of the monograph Arterial oscillography: New capabilities of the blood pressure monitor with the Oranta-AO information system (Vakulenko D. et al., Chapter 1-43, 2023). This Chapter presents a fragment of the results of our latest research.

2. Objective

The aim of our research was to identify changes in autonomic balance in patients with depressive disorders using the method of arterial oscillography (Selskyy et al., 2018; Romaniv et al., 2022; Martseniuk et al., 2007, 2018, 2020, 2021, 2022; Mintser et al., 2020 & Vakulenko et al., 2015, 2017 - 2022).

3. Materials and Methods

The study was based on the experience of analyzing the results of more than 4000 ACOGs (Vakulenko et al., 2021). In addition, 161 clinical trial participants aged 18 to 65 years were examined. Anxiety and depression levels were assessed using the Hospital Anxiety and Depression Scale (HADS). Additionally, each participant was recorded an ECG, rheogram, arterial oscillogram and laboratory determination of the general blood count. The criteria for evaluating HADS data are: 0-7 points - normal; 8-10 points - subclinically expressed anxiety/depression; 11 and above - clinically expressed anxiety/depression. The test results revealed depression scores ranging from 0 to 16. For ease of analysis, the data were divided into groups: from 0 to 3 in 66 people, from 4 to 5 in 36 people, from 6 to 10 in 42 people, and from 10 to 16 in 17 people.

We also examined 25 patients aged 32-65 years who were treated at the Ternopil Regional Clinical Psychoneurological Hospital with mental disorders. The examination program included a clinical and psychological study (clinical interview, psychological interview, psychological history). The degree of mental and psychotic disorders was assessed using the Hospital Depression Rating Scale (HDRS) and the Depression, Anxiety, Stress Scale (DASS-21). The main range of diagnoses was bipolar affective disorder132 with a current episode of depression and depressive disorders without psychotic inclusions with depressive syndrome of varying severity. AOG was recorded when the patient was admitted to inpatient treatment. A temporal and spectral analysis of the arterial oscillations was conducted during blood pressure measurements, considering both positive and negative extremes (Selskyy et al., 2018; Romaniv et al., 2022; Martseniuk et al., 2007, 2018).

Furthermore, the influence of a five-minute viewing of the video composition “Water” on the functional state of the cardiovascular and nervous systems was studied in 20 individuals without any health complaints, using arterial oscillation methodology. Arterial oscillations were recorded both before and after viewing the video composition “Water.” Evaluation was performed based on the results of temporal analysis of the arterial oscillations. The following indicators were used for the temporal analysis: HR, Moda; AMo; SDSD, pNN50; BP deltaX; IN, IVR, PAPR, HRV, RR std, and - power_osc_stdev (Martseniuk et al., 2007, 2018, 2020, 2021, 2022 & Klapchuk et al., 2007)).

Spectral analysis: TR, HF, LF, ULF (Bayevsky et al., 2001, 2017 ; Fazekas et al., 1993 & Heart, 1996). By indicators in the ranges: 0-4 Hz (Delta), 4-8 Hz (Theta), 8-13 Hz (Alpha), 13-25 Hz, 25 Hz and more Hz (Beta), it was possible to determine the level of brain activity. For this purpose, the Fourier and Hilbert-Huang transforms were used, which reflect the general and instantaneous adaptive response to shoulder compression (Bayevsky et al., 2001, 2017;

Safar et al., 2001; Yarilov, 2001). The complex indicator of regulatory systems activity (PARS) was also studied,

The results were statistically analyzed using the computer program Statistica, the Student's t-test was used for normally distributed data, otherwise the Wilcoxon method was used. Changes in indicators were considered statistically significant at $p < 0.05$.

4. Results

4.1. Time Analysis

In patients with depressive disorders, a steady upward trend in the mode amplitude (AMo) was noted. This indicator reflects an increase in the number of cardiac intervals of the same duration, which indicates the stabilization of the rhythm.

Thus, even in clinically mild cases of depression, an increase in this indicator was observed, followed by a further rise with increasing severity of depression. In the control group, this indicator was 33.49±0.14, whereas in cases of mild mental disorders, it reached 39.16±2.33, and in severe cases, it was 48.63±2.85. These changes result from the activation of the central circuit through enhanced sympathetic influences triggered by mental stress, aimed at emergency mobilization. This pattern of changes in this indicator indicates insufficient limitation of the examined organism's functional reserves. It is advisable to provide the quantity of indicators by levels in the table.

These data confirm the patterns of changes in the Regulatory Systems Activity Index (RSAI): by disease subgroups, this index in patients with depression and moderate depression was 7.1, while in healthy people its level was 3.4. The rapid growth of the indicator also indicates a sharply pronounced functional stress that arose on the basis of limited functional capacities of the reserves.

The mode indicates the most likely level of sinus node function. The higher the value of the index, the more the activity of the sinus node functioning increases. In our studies, the modal index remained virtually unchanged, so we can assume that the activity of the sinus node is stable under conditions of depression.

The trend of changes in HRV was interesting. In patients with a mild degree of depression, BP increased, but the deterioration of the patient's mental state led to a gradual but steady decrease in this indicator. Severe forms of depression were characterized by a decrease below normal. Thus, in healthy individuals, it was 0.27±0.01 s, and subsequently decreased to 0.21±0.02. Probably, minor changes in the mental state demonstrate the inclusion of adaptive mechanisms that try to bring the imbalance back to normal, but in the conditions of progression of depression or its primary severe form, adaptive mechanisms cannot cope with the load.

The stress level can be quantified using the stress index (SI) of regulatory systems. In our patients, its changes were wave-like, namely, in mild depression, a sharp decrease was observed, which again, obviously, is protective and reflects the inclusion of powerful defense mechanisms in the early stages of the disease, or is evidence of a minor stress factor, the strength of which is less than the body's capabilities. Further progression of mental function depression or exposure to an intense stressor leads to an increase in the ISh. This point demonstrates the depletion of rapid response resources and the vulnerability of regulatory

systems. The next stage is a repeated decrease in the index to the baseline level, along with the fact that the severity of depression symptoms in these patients was greater. This dynamic, in our opinion, is the result of another wave of adaptive capacities that activates other, more powerful mechanisms. When these mechanisms are ineffective or depleted, the ISh increases sharply to high levels.

4.2. Spectral Analysis

The changes in the spectral analysis indicators were interesting and quite informative, since changes in the emotional background caused significant changes in the wave structure of the heart rhythm.

Thus, there was a significant decrease in all analyzed positive indicators of spectral analysis, with the exception of %HF, although there was a significant variation in their reactions. These changes indicate the activation of the sympathetic division of the autonomic nervous system. The observed and confirmed decrease in LF activity indicates a decrease in the activity of lower regulatory centers and the leading control of central circuits.

Despite the reactivity of all the analyzed indicators, the most significant changes were for %LF and TP. It is noteworthy that %LF, which reflects the activity of the vasomotor center, remained close to the baseline in case of minor mental disorders, but with increasing severity of depression, the index decreased sharply. Thus, LF showed a significant decrease in depression 4-5. In patients with more severe depression, the index increased, almost reaching the control level, but then decreased again and its lowest level reached -31% compared to healthy individuals.

Changes in NF were characterized by a gradual increase in value, with the exception of a slight decrease in patients with moderate depression, indicating activation of the parasympathetic link of the autonomic nervous system. Under conditions of stressful tension of the regulatory systems, one can think about the compensatory inclusion of vagal mechanisms to stabilize autonomic control and attempts to limit the control of the sympathetic department.

Thus, if the changes in the process of adaptive reactions are multidirectional, we can talk about the effectiveness of adaptive reactions.

Changes in %VLF were characterized by a steady decline. In patients with severe depression, it was 39.2% lower compared with healthy people, which was a statistically significant difference ($p < 0.05$).

As for the changes in the negative spectral intervals, they were characterized by somewhat different features. Thus, the %VLF index changed in a wave-like manner. Basically, its changes were characterized by an increase during the examinations with the most significant increase, which amounted to 50.42% and was statistically significant ($p < 0.05$) in severe depression. A sharp decrease in the index was noted in moderate severity of depressive reactions.

The %LF score also showed an upward trend: from mild to severe forms of depression, but in severe forms, the score returned to its original value (Goss et al., 2013; Martseniuk et al., 2007, 2018, 2020, 2021, 2022; Vakulenko et al., 2015, 2019 – 2022; Romaniv et al., 2022 & Babunts et al., 2002).

NF decreased sharply already in minor emotional disorders and reached a minimum level in depression 4-5, when it differed from the control level by 12.15% and was statistically significant ($p < 0.01$). With increasing severity of depression, %HF reached the baseline level.

The changes in the total spectral power index, which underwent a gradual decrease, were unidirectional in demonstrating changes at the level of the heart and vascular bed. These changes indicate a significant suppression of the functional capacity of all levels of regulation by the vascular hemodynamic factor. Although it should be noted that the greater intensity of changes concerned the mechanisms of vascular regulation compared to the effects of the heart, so it can be argued that the changes in the vessels are actually efforts aimed at maintaining vegetative balance and cause adaptive protective mechanisms in relation to the heart.

Upon reviewing the decomposition of "Water" the following parameters were studied: AMo, IN, VR, IVR, and RMSSD. The AMo indicator remained unchanged during positive extremes, while AMo neg decreased during negative extremes. IN-pos and IVR-pos significantly increased, whereas IN-neg and IVR-neg behaved diametrically opposite, decreasing. VR-pos and VR-neg reacted ambiguously: the former significantly decreased, while the latter increased. Additionally, the RMSSD indicator showed a significant decrease after video review.

Therefore, after reviewing the decomposition of "Water" based on the time analysis parameters of HRV, there was an ambiguous trend observed in the studied indicators. Positive extremes (reflecting the state of the cardiac component of hemodynamics) showed a significant increase in sympathetic nervous system activity. Conversely, negative extremes (reflecting the activity of the vascular component of hemodynamics) led to an increase in parasympathetic activity of the autonomic nervous system. Thus, the review of the decomposition of "Water" contributed to increased activity of the sinoatrial node and peripheral vessel dilation. This was corroborated by the aforementioned indicators obtained during the analysis of depressive states. The predominant changes also pertained specifically to the vascular component of hemodynamics and depended on the level of depressive states. It can be asserted that these vascular changes represent efforts aimed at maintaining autonomic balance and induce adaptive protective mechanisms for the heart.

Conclusion

1. The analysis of arterial oscillograms recorded during blood pressure measurement and the use of the Oranta-AO Information system (developed by the co-authors) made it possible to study the state of the autonomic nervous system and cardiac and vascular hemodynamic factors in depressive mental disorders.
2. Activation of the sympathetic-adrenal system is a determinant factor in the development of adverse cardiac events. In depressive disorders of varying severity, an imbalance in the control of the cardiovascular system has been identified, which has a negative impact on heart rate variability and may be an unfavorable factor for the further development of cardiovascular complications.
3. In depressive disorders, there are disorders of the functional capacity of all levels of regulation by the vascular (as well as cardiac) hemodynamic factor. This is confirmed by changes in HRV and the percentage of low- and ultra-low-frequency components, ANS imbalance; a decrease in the total power of the spectrum. The above-mentioned complicates the work of the heart itself, because the efferent sympathetic and vagal activation directed to the sinus node can be modulated by central (vasomotor,

respiratory centers) and peripheral (the main component of which is blood vessels) influences.

4. Assessment of cardiohemodynamic parameters in patients with a tense psycho-emotional state is an extremely important diagnostic measure. The results of cardiac intervalometry (oscillography) may suggest which regulatory links are affected and make it possible to identify mechanisms that will worsen the prognosis of such patients.

   Thus, we have established that an important mechanism of depressive syndrome's effect on the body is the activation of the sympatho-adrenal system, which affects vasoconstriction, regulation of heart rhythm and is manifested by low heart rate variability (HRV), which is directly related to the severity of the depressive syndrome. At the same time, studies have shown that the described changes are accompanied by the inclusion of regulatory mechanisms aimed at increasing the tone of the parasympathetic nervous system and weakening the imbalance of the autonomic system as a whole, improving adaptive responses. It can be argued that mental disorders, namely depressive disorders, are the basis for the development of certain cardiovascular problems, and early detection of predispositions to these problems is an important task.
5. Conducting a time analysis of HRV (Heart Rate Variability) based on positive and negative extremes has demonstrated that the review of the “Water” decompensation contributes to increased activity of the sinus node, peripheral vessel dilation, and facilitates cardiac function. This is supported by the previously described results of the analysis of depressive states: predominant changes are also related to the vascular component of hemodynamics and depend on the degree of mental and psychotic disorders. It can be argued that vascular changes are efforts aimed at maintaining autonomic balance and trigger adaptive protective mechanisms for the heart. The review of the “Water” decompensation can be used to correct the functional state of the autonomic nervous system and mental well-being.

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