Abstract

The presented work aims to investigate the complexity of the cardiovascular system and its interactions with other body systems, such as the respiratory and nervous systems. We focus on utilizing advanced methods of biological signal analysis, such as transfer entropy and signal symbolization, to better understand the human body's dynamic relationships and adaptive regulatory mechanisms. The goal is to explore physiological regulatory processes in greater detail and highlight potential applications of these methods in diagnosing and monitoring health status. Thus, the thesis aims to expand knowledge of the complex interactions within the cardiovascular system.

Chapter 1 of the doctoral thesis introduces the analysis of multidimensional data concerning the cardiovascular system, emphasizing the complexity and significance of dynamic systems. It discusses the classification of dynamic systems, including their continuous, discrete, linear, nonlinear, stable, and unstable properties, focusing on nonlinear systems exhibiting complex behaviors. Subsequently, it presents the analysis of the probability density distribution of nonlinear signals using histograms and the application of Shannon entropy as a measure of signal complexity and transfer entropy as a measure of causality. The concept of symbolic dynamics is then introduced, along with examples of its application in biological signal analysis. The second part of Chapter 1 focuses on the physiological basis of modeling interactions within the cardiovascular system. It describes essential feedback mechanisms such as blood pressure regulation, blood flow autoregulation, and heart rate control. The significance of the autonomic nervous system is highlighted, playing a crucial role in modulating heart and blood vessel functions through the sympathetic and parasympathetic systems. The impact of baroreceptors, chemoreceptors, and other sensory mechanisms on cardiovascular homeostasis is also discussed. Special attention is given to the role of mathematical models in understanding these complex relationships, enabling accurate representation of physiological processes and forecasting their behaviors in various pathological and physiological states.

Chapter 2 presents a series of four publications focusing on analyzing interactions and complexity within the cardiovascular system using advanced methods of biological signal analysis. The first publication investigates causal relationships within the cardiovascular system using transfer entropy, demonstrating the pivotal role of the baroreflex in maintaining blood circulation homeostasis during tilt testing. The second publication analyzes the complexity of cardiovascular rhythms during orthostatic testing, introducing a novel method of signal symbolization using dynamic patterns that differentiate healthy individuals from those with vasovagal reactions. The third publication further develops signal symbolization

methods, applying them to analyze the dynamics of cardiovascular couplings, confirming the effectiveness of dynamic patterns in detecting real interactions between blood pressure signals and heart rhythm. The fourth publication introduces a model of interaction between the respiratory and cardiovascular systems, analyzing the influence of respiratory phases on RR interval variability and arterial pressure, providing a basis for further modeling of relationships between these systems. This series of publications demonstrates the advancement of signal analysis methods in cardiovascular regulation research and their potential to distinguish between health and disease states.

Chapter 3 provides a detailed summary of the main findings and discoveries presented in this thesis. It synthesizes the results from the four described publications, which analyze various aspects of interactions and complexity within the cardiovascular system using advanced methods of biological signal analysis. Following this summary, the bibliography containing the references cited throughout the publications is included. Subsequently, the texts of the published articles are provided, detailing the methodology, results, and conclusions of each study. Finally, the thesis concludes with the "Author's Profile" section, presenting information about the author of the thesis and her achievements.