Cardiovascular and Cardiorespiratory Interactions – From Physiological Mechanisms to Clinical Applications
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Analysis of Respiratory Heart Rate Variability Using Ordinal Patterns with Ties and Tolerance

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We propose a new approach based on the analysis of ordinal patterns to investigate respiratory heart rate variability (RespHRV), also known as respiratory sinus arrhythmia (RSA). We introduce ordinal patterns with ties and tolerance as a new method for symbolization of heart rate changes. By aligning heart rate data to the respiratory cycles, we analyze changes in heart rate at different phases of the respiratory cycle. The method uses RR interval time series derived from ECG signals, together with simultaneous respiratory recordings obtained with a respiratory belt. The method produces distributions of ordinal patterns that reflect the dynamics of heart rate variability throughout the respiratory cycle.

The approach will be illustrated using data from patients with obstructive sleep apnea (OSA) and healthy controls. Particular attention will be given to how introducing tolerance for small differences between RR intervals changes the observed pattern distributions and their physiological interpretation. The findings suggest that this approach may provide new insights into alterations in cardiorespiratory regulation associated with OSA.

[1] B. Graff, P. Pilarczyk, M. Elstad, K. Narkiewicz and G. Graff. Ordinal patterns with ties and tolerance provide a physiology-driven method to quantify cardiorespiratory interactions. *Biomedical Signal Processing and Control* **129** (2027), 111312. doi:10.1016/j.bspc.2026.111312