Ventricular Fibrillation Dynamics: Manifold Learning and Neural Network Approach

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Introduction. Ventricular Fibrillation (VF) is a life-threatening cardiac arrhythmia characterized by rapid and erratic heartbeats, which can lead to sudden cardiac death. Moreover, conventional methods for analyzing the patterns of heart rhythms are not able to fully explore the different origins of VF. Therefore, VF occurring during cardiopulmonary bypass (CPB) surgeries offers a unique opportunity to study how VF develops in real human situations. This study focuses on identifying and classifying the two types of VF which happen during surgery and understanding its mechanisms and patterns. **Methods**. This research aims to apply manifold learning and deep learning methods to classify the two types of VF during CPB (FVON and FVOFF). Initially, an examination of the low-dimensional latent space was conducted using supervised Uniform Manifold Approximation and Projection (UMAP), revealing a separation between the two types of signals. To further investigate the presence of feature differences, neural network architectures were used. Specifically, Temporal Convolutional Neural Networks (TCNs) were applied to both the temporal signal and the frequency evolution of each signal. **Experiments and Results**. The VF signal database used in this work contains VF ECG data from twelve patients experiencing fibrillation when the heart stops during aortic cross-clamping (VFON), and from seventeen patients experiencing fibrillation before the heart begins functioning at releasing aortic cross-clamp (VFOFF). Experimental results demonstrate the accurate identification of both classes, with a classification accuracy of 0.8180 achieved using UMAP and 0.9052 achieved using TCN, when considering frequency evolution of each signal. **Conclusion**. The results from UMAP and TCN demonstrated the capability to distinguish between different classes of VF during CPB, indicating variations in frequency and pattern evolution of the signals. Observed patterns in the frequency domain were found to be more easily identifiable than those in the temporal domain.