Analysis of Phase Singularities in Experimental Optical Mapping Data of Isolated Rat Hearts Experiencing Ventricular Fibrillation Using Phase Mapping and Directed Graph Mapping

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Ventricular fibrillation (VF) is a severe cardiac arrhythmia characterised by irregular electrical activity originating from the heart's ventricles. However, mapping this arrhythmia is challenging due to its erratic nature. Optical mapping offers a solution by employing an LED light source and fluorescent dyes sensitive to electrical tissue activity. This technique enables simultaneous recording of large areas of cardiac tissue using a photodetector, facilitating the detection of hypothesised mechanisms such as stable and semi-stable rotors. In this study, VF was induced in isolated rat hearts, and cardiac dynamics were observed through optical mapping. We introduce Directed Graph Mapping (DGM), a software tool designed for reading, filtering, analysing and visualising electroanatomical mapping data containing both rotational and focal activity. DGM utilises graph-theory techniques for graph construction and subsequent analysis, including directed cycle detection, focal source identification, Helmholtz decomposition, and clusterisation methods. Additionally, our framework incorporates Phase Mapping (PM), which generates phase maps, identifies phase singularities (PS), and clusters PS in both temporal and spatial dimensions. Applying this software to optical maps, we are able to compare the efficacy of three methods for detecting stable rotors: 1) Cycle search, 2) Helmholtz decomposition, and 3) Phase Mapping. Visual comparison reveals a general consensus among the methodologies, particularly in detecting stable and semi-stable rotors. Therefore, this agreement enhances confidence in rotor identifications, specifically in cases where the ground truth of the data is lacking. DGM's integrated approach offers a comprehensive framework for analysing VF, potentially advancing our understanding of underlying mechanisms and informing therapeutic interventions.