Tikhonov and TSVD Comparison for Epicardial Potential Estimation Across Different Cardiac Rhythms: Insights from an Animal Model Study

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Introduction: Electrocardiographic imaging (ECGi) provides a promising approach to estimate heart potentials using signals from the torso surface. The Tikhonov regularization method has been widely applied in literature. This study compares reconstructed epicardial electrograms estimated through Tikhonov and Truncated Singular Value Decomposition (TSVD) regularization methods, under sinus rhythm (SR) and atrial arrhythmia (AA), obtained in torso-tank rabbit model.

Methods: The experimental setup has an epicardial electrical mapping (Fs: 4 kHz) composed by 3 microelectrode arrays (16 electrodes each) placed in the atria and ventricle, respectively. Moreover, the heart is immersed inside a torso-tank setup filled with conductive sucrose solution, where 60 electrodes are distributed equally across a hexagonal translucent tank (10 electrodes per face). 3D reconstruction of the rabbit heart is performed. Leveraging signals from the tank and the 3D geometries (tank and heart), ECGi allowed obtaining 3 seconds segment of epicardial reconstructed unipolar electrograms through the Tikhonov and TSVD regularization methods (orders 0, 1, 2). The Root Mean Square Error (RMSE) quantified accuracy between estimated and measured signal.

Results: 3D potential maps from ECGi during each rhythm revealed distinct electrical activity patterns. Precision in estimating epicardial potentials varies across cardiac conditions and regularization methods. During SR, Tikhonov exhibited lower RMSE values: 4.6, 0.6, and 0.1 for orders 0, 1, and 2, respectively. TSVD showed slightly higher errors: 0.3, 0.4, and 0.3 for orders 0, 1, and 2. The AA yielded to larger errors. Tikhonov reported higher RMSE values compared to SR: 39.1, 3.1, and 1.0 for orders 0, 1, and 2, respectively. TSVD also displays increased errors, ranging from 11.7 to 9.4 across all orders.

Conclusion: Two different regularization methods were applied in a torso-tank setup to estimate reconstruct electrograms during SR and AA. The Tikhonov order 2 performed better. The analysis will be expanded to other arrhythmias.