Effects of ECG Signal Processing on the Inverse Problem of Electrocardiography

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Background: The inverse problem of electrocardiography (ECGI) is ill-posed. Errors such as signal noise can impact the accuracy of reconstructed cardiac activity. It is currently not known how sensitive ECGI is to different signal pre-processing techniques. A workgroup of researchers from different institutes was created at CINC 2017 to investigate this void.
Methods: Experimental data from a Langendorff-perfused pig heart suspended in a human-shaped torso-tank was used. Epicardial electrograms were acquired during 30s of pacing using a 108-electrode array, simultaneously with torso potentials from 128 electrodes embedded in the tank surface. Processing methods were divided into three categories i) high-frequency noise removal (Filt-High) ii) baseline drift removal (BDR) and iii) signal averaging (SA). Tank ECGs were processed using each method (alone or combined with other methods), culminating in n=91 different signals. For each signal, the inverse problem was solved using Tikhonov regularization and L-curve to define the regularization parameter. Reconstructed electrograms and activation times were compared to those recorded by the sock for 3 beats selected throughout the recording.
Results: Electrograms reconstructed after BDR and/or SA had amplitudes up to three-fold larger than with no processing (*p<0.05), though still smaller than recorded electrograms (**p<0.0001) as measured by mean RMS voltage. Only one method (the rational transfer function) reported any improvement in electrogram QRS morphology as measured by correlation (p=0.02). Filt-High methods improved reconstructed electrogram smoothness compared to raw signals (*p<0.0001), while other methods reduced smoothness (**p<0.0001) as measured by a lag-5 ms autocorrelation. Filt-High and SA (alone or with BDR) substantially improved activation detection with correlation values up to 0.4 greater than without preprocessing. BDR alone tended to marginally reduce activation accuracy.
Conclusions: Signal pre-processing methods can have a dramatic effect on ECGI reconstructions accuracy, particularly for activation time detection where processing to remove high frequency noise is very important.