Reduction of Effects of Noise on the Inverse Problem of Electrocardiography with Bayesian Estimation

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Background: Due to the ill-posed nature of the inverse problem of electrocardiography, regularization should be used to stabilize the solutions. In a companion study, we showed that noise in the measurements, and application of signal preprocessing methods significantly influence the accuracy of electrogram reconstructions. Bayesian MAP estimation has potential to reduce these effects with careful statistical modeling.
Methods: Experimental data from a Langendorff-perfused pig heart suspended in a human-shaped torso-tank was used. Epicardial electrograms were acquired during 30 s of RV pacing using a 108-electrode array, simultaneously with torso potentials from 128 electrodes embedded in the tank surface. Electrograms were reconstructed using Bayesian MAP estimation, assuming jointly Gaussian epicardial and torso potentials, for raw (unfiltered), and filtered tank ECG measurements. Leave-one-beat-out protocol was used to obtain the prior probability density function (pdf) of electrograms, and noise statistics. Noise pdf was assumed to be Gaussian with zero mean. Two different noise models were used; a) independent and identically distributed (noi-iid), b) correlated (noi-corr). Reconstructed electrograms and activation times were compared to those directly recorded by the sock for 3 beats selected throughout the recording.
Results: noi-corr reconstructed electrograms with better morphology and magnitude than noi-iid (mean CC 0.34-0.37 higher and mean RMSE 16.9-18.3 mV lower; $p<0.0001$). For both noi-iid and noi-corr, the preprocessing methods used did not significantly alter electrogram reconstruction in terms of mean CC or mean RMSE ($p>0.05$). Qualitative analysis of electrograms showed that despite better overall topology, there was more high-frequency noise in noi-corr reconstructions than noi-iid. This was reflected in activation times reconstructed using these methods where noi-corr reconstructions were only superior when high frequency noise removal methods were used.
Conclusions: noi-corr is superior to noi-iid, but for applications requiring activation time derivation, careful selection of preprocessing methods, in particular to adequately remove high-frequency noise, is needed.