Real-time System for High-Resolution ECG Diagnosis Based on 3D Late Potentials Fractal Dimension Estimation

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High-resolution electrocardiography (HRECG) is an advanced technique that enables detection of low amplitude signals in the ventricular depolarization activity, such as the so called 'late potentials' (LP). The presence of LP is widely accepted to have prognostic significance in patients after acute myocardial infarction, and in more recent studies, as a risk indicator in patients with Brugada syndrome. The signal averaged ECG (SAECG) has been the preferred denoising technique. However, implementation of SAECG can be a highly demanding real-time process if reliable QRS alignment is required under noisy circumstances. To enable reliable real-time SAECG in a portable compact HRECG system, we have embedded the SFP alignment technique in the microcontroller of the orthogonal leads ECG acquisition front stage. Also, a highly noise-immune LP quantification parameter, LPd , was implemented. LPd estimates the fractal dimension of the LP attractor within the 40 microvolts 3D space. This portable and robust HRECG system is intended for screening/monitoring subjects/patients at cardiac risk in the out-of-hospital environment. A LabVIEW application communicates with a specially built orthogonal leads ECG acquisition module, via the USB port of a laptop. System performance of the hardware, real-time SFP firmware and LabVIEW application for processing the SAECG, was tested under added noise of controlled level (50Hz and EMGsimul). LPd computation verification, was assessed by coherent synthetic LP (modeled; LPd 1.3) signal injection at the body surface, followed by signal characterization of the recovered synthetic LP output by the overall system process, in several healthy volunteers. The SFP technique was tested by adding different noise levels of 50Hz and simulated EMG (EMGsimul) to a noiseless modeled ECG of known spectrum in the reference channel. Analysis of spectral degradation due to the SFP averaging of 600 beats, indicated a negligible beat alignment jitter standard deviation under the worst noise levels (320Vrms): +/-0.82 ms, for 50Hz, and +/-0.68 ms for EMGsimul. In the computed LPd verification method, the mean value of LPd in five healthy volunteers was of 1.24 +/-0.043 SD, and after injecting the synthetic LP signal on the same healthy subjects, LPd was 1.34 +/-0.023, yielding a satisfactory LPd reproducibility performance of the LPd parameter diagnostic algorithm.