Wrist-located Optical Monitoring Device for Atrial Fibrillation Screening

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Worldwide, there is a need to reduce healthcare costs. In this context, wearable technologies are being targeted as one of the major tools of value-based self-monitoring and large screening healthcare systems. Portable Holter monitoring systems, which represent a global market of more than 150 million U.S. dollars, [1] are used to monitor patients suffering from cardiovascular diseases. The most common form of cardiac arrhythmia, affecting more than 10% of the population aged over 80 years, [2] is Atrial Fibrillation (AF). Years of research in system design and signal processing have been necessary to bring wrist-located optical devices to a state able to accurately monitor cardiac activity. [3] During the Nano-Tera project miniHOLTER, the feasibility of using such devices for the detection of AF was investigated. The present study constitutes the first clinical evidence of reliable AF detection using a wrist-located optical device.

Years of research on system design and on the enhancement of photoplethysmographic (PPG) signals have been necessary to bring PPG technology into wearable wrist-located devices able to accurately monitor cardiac activity during daily activities [3]. Some questions remain unanswered: Is the monitoring of cardiac activity accurate enough for an ambulatory application? If so, to what extent can it substitute for ambulatory electrocardiographic (ECG) devices for large-scale screening of populations? This study aims at evaluating the performance of a wrist-located device based on PPG technology in terms of Atrial Fibrillation (AF) detection using features based on cardiac interbeat (RR) intervals.

In order to validate the detection of AF, signals were recorded at the University Hospital in Lausanne (CHUV) from patients admitted for AF or ventricular tachycardia ablation. Twenty PPG and 12-lead ECG signals were recorded simultaneously from patients in whom episodes of sinus rhythm (SR) and AF coexisted. From the PPG signals, RR intervals were estimated by detecting the systolic downstrokes. From the ECG signals, RR intervals were computed from detected R-waves provided by an electrophysiology system (Siemens Sensis). The resulting PPG- and ECG-based RR intervals were used to derive feature values in 10-s time windows. These features were the mean, median, minimum, and interquartile range. A total of 2213 (1927 of AF, 286 of SR) 10-s epochs were considered for AF versus SR classification using a support vector machine with a linear kernel trained using a leave-one-out procedure to avoid overfitting.

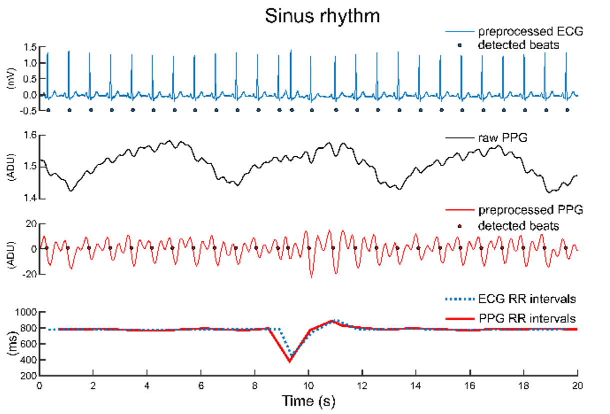

Figure 1: Example of ECG and PPG signals and post-processing results during SR.

Classification accuracies of 94 and 99% were obtained from PPG- and ECG-based features, respectively. It is interesting to compare this performance to a recently published study that compared AF detection performance between permanent pacemakers (accuracy of 99%) and implantable cardiac monitors (accuracy of 72%) [4].The detection of AF embedded in these two implementable medical devices was also based on features extracted from the time series of RR intervals.

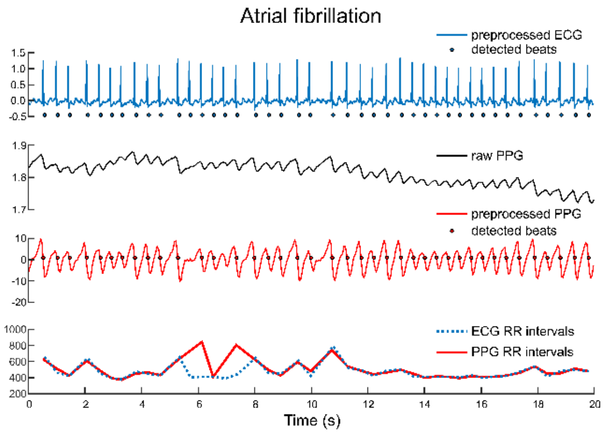

Figure 2: Example of post-processed ECG and PPG signals and post-processing results during AF.

Based on these encouraging results, the proposed wrist-located AF screening device challenges implantable cardiac monitors in controlled conditions. Several advantages over ECG-based devices must be mentioned, including the non-invasiveness, limited cumbersomeness, long-term monitoring, cost, and size. Furthermore, the possibility of integrating this technology in currently distributed smart watches and bracelets makes it very attractive for large population screening. To achieve a highly robust and accurate 24/7 AF screening device, further work is required regarding the improvement of cardiac beat detection during AF, the addition of a signal quality index in the classification procedure, and the investigation of additional features based on variation of PPG waveform morphology and magnitude.

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