Deriving Heart Rate Variability Measures from a Noninvasive, Nonintrusive, Wireless, Wrist-Based Home Monitoring Device

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Introduction. Heart rate variability (HRV) is a clinically predictive value of overall cardiac mortality that provides a means to noninvasively assess the autonomic nervous system and has been found to correlate with a wide variety of clinical conditions.1 While HRV measures traditionally have been derived from electrocardiograms (ECGs), promising results have been reported using photoplethysmography (PPG) signals, which could be more practical for long-term, outpatient-based monitoring.2 Patient adherence, ease of use, nonintrusiveness, and non-stigmatization are critical success factors for accurate data collection in home-based settings. Commercially-available HRV monitoring devices are not designed to be socially acceptable, comfortable for 24/7 long-term use, and automated with real-time data transfer, thereby decreasing likelihood of user adherence and continuous heart data capture. The goal of this research is to derive HRV measures from an existing noninvasive, nonintrusive, wireless, wrist-based home monitoring system (via a socially-acceptable “watch” device) that obtains continuous PPG signals in order to perform long-term trending of HRV metrics and, ultimately, provide earlier indication of need for intervention.3

Methods. The commercially-available platform monitoring system used in this study collects 24/7 activity data via accelerometry and other data, all of which are transmitted automatically and wirelessly via a local mesh network to a HIPAA-compliant cloud server and database for real-time trending and targeted alerting (e.g., via email) to designated care providers.3 A prototype of the system’s wrist device with PPG sensors was used to collect PPG signals with simultaneous collection of PhysioFlow® ECG signals from an individual in a laboratory setting. The largest amplitudes of each signal were detected, from which peak-to-peak intervals and heart rates were calculated. Time-domain, frequency-domain, and nonlinear HRV metrics were computed for both signals and then compared.

Results. In this preliminary analysis, a 200-beat time window was used to derive heart rates and HRV metrics (Figure 1). Sample results of HRV metrics include the following: standard deviation of all peak-to-peak intervals of 80.5 ms (ECG) and 84.6 ms (PPG); minimum peak-to-peak interval of 750.0 ms (ECG) and 774.3 ms (PPG); maximum peak-to-peak interval of 1234.4 ms (ECG) and 1378.9 ms (PPG); total power of 2622.3 mm² (ECG) and 2379.9 mm² (PPG); “detrended fractal scaling exponent”, which quantifies short-term complexity, of 0.97 (ECG) and 0.87 (PPG); and sample entropy, which measures the amount of irregularity in peak-to-peak intervals, of 1.4 (ECG) and 1.5 (PPG).

Discussion. The preliminary results show that HRV metrics can indeed be derived from PPG signals obtained via a nonintrusive, noninvasive, wristwatch monitoring system, and therefore outpatient-based long-term HRV trending with earlier indication of need for intervention (e.g., implantable defibrillator) may be feasible. Next steps involve collection of more data from multiple individuals to determine which HRV metrics are most suitable, implementation into the system, and then detailed analysis in the clinical context to determine any potential measurement differences and implications.

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References