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Assessment of Five Photoplethysmographic Methods for Estimating Heart Rate Variability

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Abstract : Heart Rate Variability (HRV) is a widely used indicator of the regulation between the autonomic nervous system (ANS) and the cardiovascular system. Besides being non-invasive, it also has the potential to predict mortality in cases involving critical injuries. The gold standard method for determining HRV is based on the analysis of RR interval time series extracted from ECG signals. However, because it is much more convenient to obtain photoplethysmogramic (PPG) signals as compared to ECG signals (which require the attachment of several electrodes to the body), many researchers have used pulse cycle intervals instead of RR intervals to estimate HRV. They have also compared this method with the gold standard technique. Though most of their observations indicate a strong correlation between the two methods, recent studies show that in healthy subjects, except for a few parameters, the pulse-based method cannot be a surrogate for the standard RR interval-based method. Moreover, the former tends to overestimate short-term variability in heart rate. This calls for improvements in or alternatives to the pulse-cycle interval method. In this study, besides the systolic peak-peak interval method (PP method) that has been studied several times, four recent PPG-based techniques, namely the first derivative peak-peak interval method (P1D method), the second derivative peak-peak interval method (P2D method), the valley-valley interval method (VV method) and the tangent-intersection interval method (TI method) were compared with the gold standard technique. ECG and PPG signals were obtained from 10 young and healthy adults (consisting of both males and females) seated in the armchair position. In order to de-noise these signals and eliminate baseline drift, they were passed through certain digital filters. After filtering, the following HRV parameters were computed from PPG using each of the five methods and also from ECG using the gold standard method: time domain parameters (SDNN, pNN50 and RMSSD), frequency domain parameters (Very low-frequency power (VLF), Low-frequency power (LF), High-frequency power (HF) and Total power or “TP”). Besides, Poincaré plots were also plotted and their SD1/SD2 ratios determined. The resulting sets of parameters were compared with those yielded by the standard method using measures of statistical correlation (correlation coefficient) as well as statistical agreement (Bland-Altman plots). From the viewpoint of correlation, our results show that the best PPG-based methods for the determination of most parameters and Poincaré plots are the P2D method (shows more than 93% correlation with the standard method) and the PP method (mean correlation: 88%) whereas the TI, VV and P1D methods perform poorly (<70% correlation in most cases). However, our evaluation of statistical agreement using Bland-Altman plots shows that none of the five techniques agrees satisfactorily well with the gold standard method as far as time-domain parameters are concerned. In conclusion, excellent statistical correlation implies that certain PPG-based methods provide a good amount of information on the pattern of heart rate variation, whereas poor statistical agreement implies that PPG cannot completely replace ECG in the determination of HRV.

Keywords : photoplethysmography, heart rate variability, correlation coefficient, Bland-Altman plot
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