Effect of aging on pulse rate variability for evaluating autonomic nervous system

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Summary

To determine whether the short-term assessment of pulse rate variability (PRV) is a surrogate for that of heart rate variability (HRV) in an elderly population under resting conditions, we collected photoplethysmography (PPG) and electrocardiography (ECG) signals simultaneously, and analyzed their association and agreement with HRV and PRV components. We divided the elderly population into three groups, namely, those younger than 70 years (< 70 yrs), those older than 70 years and younger than 80 years (70–79 yrs), and those older than 80 years (≥ 80 yrs), and we found that PRV was more underestimated than HRV with increasing age, although the PRV components highly correlated with the HRV components in the three groups. Thus, PRV can be used to examine the autonomic nervous system (ANS) function in elderly populations. However, the interpretation of results should consider the effect of aging, particularly in those older than 80 years.

Key words

heart rate variability (HRV), pulse rate variability (PRV), autonomic nervous system

Introduction

The determination of heart rate variability (HRV) derived from electrocardiography (ECG) signals has been used as a noninvasive technique to examine the autonomic nervous system (ANS) function. 1), 2) In addition, pulse rate variability (PRV) is also used as an alternative modality for HRV, particularly in situations wherein ECG is not available or cannot be performed owing to electrical artifacts. 3) The components of this variability highly correlate with HRV components in a young or adult population, 4), 5) whereas previous studies showed that PRV is not a surrogate for HRV in standing healthy subjects and in patients with low HRV. 6), 7) Recently, the link between aging and ANS function in rats, mice, and humans has been reported, 8)–12) and thus we examined whether the frequency domain components of PRV derived from photoplethysmography (PPG) signals are surrogates for HRV derived from ECG signals in elderly populations under resting conditions.

Materials and Methods

In this study, 73 outpatients [23 male and 50 female subjects; 78.7 years old ± 8.4 standard deviation (SD)] receiving medical care at Hyogo Prefectural Rehabilitation Center at Nishi-Harima in Japan were included. This study was approved by the ethics committee of the institution.

The examinations were performed in the supine position during spontaneous breathing. Lead II ECG signals and PPG signals were collected simultaneously for 150 s with one electrode on the right wrist (negative) and two on the left leg (positive and ground) for ECG, and the PPG sensor on the fingertip of the left hand for PPG. The frequency domains of HRV derived from ECG were analyzed by the maximum entropy method (MEM) (Reflex Meijin, CROSSWELL, Yokohama, Japan). Acceleration plethysmogram (APG) was obtained from the second derivative of a PPG signal, and the frequency domains of PRV, based on APG, were analyzed by the fast Fourier transform (FFT) method (Pulse Analyzer...
Results

In the elderly population (mean age, 78.7 years, n = 73), the correlation coefficients (r) for HR, LF, and HF, and the L/H ratio were 0.999 (95% confidence interval, 95% CI: 0.997–0.999), 0.943 (0.911–0.964), 0.930 (0.891–0.956), and 0.897 (0.840–0.934), respectively. The mean differences in HR, LF, HF, and L/H ratio were −0.51 (lower and upper limits of agreement: −1.23, 0.22), −36.1 (−126.5, 54.4), −10.9 (−56.4, 34.5), and −1.0 (−5.26, 3.19), respectively. These results suggest that PRV can be a surrogate for HRV in the elderly population. Thus, to examine the effect of aging on frequency components in PRV, we next divided the participants into three groups, namely, (1) those younger than 70 years (< 70 yrs), those older than 70 years and younger than 80 years (70–79 yrs), and those older than 80 years (≥ 80 yrs) (Table 1). When we compared with the ratio of PRV to HRV components, LF, HF, and L/H tended to gradually decrease with age (Table 2). Furthermore, the slopes of regression curves in all the components gradually decreased with age (Figure 1). In particular, the slopes of regression curves in HF (y = 0.6897x + 5.5114) and LF (y = 0.6983x − 9.0331) components in the ≥ 80 yrs group were lower than those in the < 70 yrs (y = 0.9506x + 1.4551, p = 0.021, pcorr = 0.063) and 70–79 yrs groups (y = 0.8384x − 14.867, p = 0.032, pcorr = 0.096). Interestingly, Bland–Altman plot analysis revealed that the slopes of HF (y = −0.3192x + 3.9808) and LF (y = −0.3193x − 13.627) components in the ≥ 80 yrs group were significantly higher than those in the < 70 yrs group (y = 0.0483x − 7.2394, p = 0.005, pcorr = 0.015 and y = 0.0134x − 30.397, p = 0.0007, pcorr = 0.0021, respectively). In addition, those of LF (y = −0.3193x − 13.627) and L/H ratio (y = −0.7556x + 8.97) in the ≥ 80 yrs group were also higher than those in the 70–79 yrs group (y = −0.1366x − 19.581, p = 0.0027, pcorr = 0.081 and y = −0.255x − 0.4714, p = 0.017, pcorr = 0.051, respectively) (Figure 2). These results suggest that the frequency components derived from PRV were more underestimated than those derived from HRV depending on age.

Discussion

In this study, we compared the PRV components from PPG with the HRV components from ECG in the supine position during spontaneous breathing in an elderly population, and found a high correlation between PRV and HRV. However, when we divided the participants into three groups, namely, (1) those younger than 70 years old, (2) those older than 70 years and younger than 80 years, and (3) those older than 80 years, we found for the first time that PRV was more underestimated than...
HRV depending on age, although the PRV components were highly correlated with the HRV ones in all the three groups.

It has been reported that HRV is significantly reduced in patients with diabetes mellitus compared with healthy controls.\(^{14}\) We further eliminated these patients and then compared the slopes of regression curves obtained from the Bland–Altman plot between the < 70 yrs (n = 9) and ≥ 80 yrs groups (n = 39). As similarly shown in Figure 2, the slopes of HF (y = −0.3233x + 3.6705) and LF (y = −0.2242x − 17.481) components in the ≥ 80 yrs group were significantly higher than those in the < 70 yrs group (y = 0.0421x − 3.3094, \(p = 0.006\), \(p_{\text{corr}} = 0.018\) and \(y = 0.0042x − 25.595, p = 0.0165, p_{\text{corr}} = 0.049\), respectively, data not shown). In addition, the percentage of patients with hypertension tended to be higher in the ≥ 80 yrs group (31/42, 73.8%) than in the < 70 yrs group (4/10, 40%). When we further divided the ≥ 80 yrs group into two, namely, those with or without hypertension, the Bland–Altman plot analysis revealed that the slope of HF components did not differ between the patients with (y = −0.3393x − 1.4071) and without (y = −0.1469x − 1.4071) hypertension (\(p = 0.26\)). As a result, the slope of LF components in the patients with hypertension (y = −0.2466x − 15.182) was significantly lower than to those in the patients without hypertension (y = −0.5788x − 7.8258) (\(p = 0.0012, p_{\text{corr}} = 0.0036\), data not shown). It seems that PRV was more underestimated than HRV depending on age, but this underestimation was unrelated to the presence of diabetes mellitus and hypertension. However, to elucidate the precise contributions of these diseases, further studies are required.

Previous studies have shown that aging affects ANS function. Pulse wave velocity (PWV) was found to be associated with ANS status, such as orthostatic pressor response, heart rate variation during deep breathing, and immediate heart rate response upon standing in those older than 65 years,\(^{12}\) and aortic artery distensibility showed an inverse correlation with HRV in elderly nonhypertensive and cardiovascular-disease-free individuals.\(^{11}\) In addition, the main difference between HRV and PRV is the pulse transit time (PTT), which is the time that the pulse wave takes to travel from the heart to the fingers. Since PTT changes beat to beat and is closely related to arterial compliance and blood pressure,\(^{15}\) PRV could be affected by the variability of
PTT caused by aging.

In conclusion, we demonstrated in this study that the frequency domain components of PRV highly correlated with those of HRV, and PRV can be used to examine the ANS function in elderly populations. However, the interpretation of results should consider the effect of aging, particular in those older than 80 years.

References


Figure 2  Bland–Altman plot for HR, LF, HF, and L/H ratio in those younger than 70 years (< 70 yrs, n = 10, ○), those older than 70 years and younger than 80 years (70–79 yrs, n = 21, △), and those older than 80 years (≥ 80 yrs, n = 42, □). The solid line represents the regression curve of the respective groups. The Bland–Altman plot analysis revealed that the slopes of HF (y = −0.3192x + 3.9808) and LF (y = −0.3193x − 13.627) components in the ≥ 80 yrs group were significantly higher than those in the < 70 yrs group (y = 0.0483x − 7.2394, p = 0.005, p corr = 0.015 and y = 0.0134x − 30.397, p = 0.0007, p corr = 0.0021, respectively).

There is no potential conflict of interest to disclose.

原 契

加齢が脈拍変動解析にもたらす影響

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要 旨

高齢者の自律神経機能を評価する場合, 短時間での脈拍変動解析 (PRV) が心拍変動解析 (HRV) の代替法となりうるか, 光電式容積脈波記録法 (PPG) と心電図記録法 (ECG) の同時測定により評価した。被験者を 70 歳未満, 70 歳以上 80 歳未満, 80 歳以上の 3 群に分類した場合, すべての群において PRV 由来の周波数成分は HRV 由来の周波数成分と強い相関を示したものの, 其の絶対値は高齢になるにつれて低値を示した。すなわち, PRV は高齢者の自律神経機能を評価するスクリーニング法としては有用であるが, その結果の解釈は, 特に 80 歳以上の高齢者において HRV で測定した場合よりも過小評価されていることを考慮する必要があるかもしれない。

キーワード：心拍変動, 脈拍変動, 自律神経系

（平成 29 年 8 月 2 日受付・平成 30 年 1 月 18 日受理）