Effects of Posture and Breathing Frequency on Baroreflex Measurements

EJ Bowers, A Murray

Regional Medical Physics Department, Freeman Hospital, Newcastle upon Tyne, UK

Abstract

The aim of this study was to assess the influences of posture and breathing frequency on baroreflex measurements.

Six normal healthy volunteers breathed regularly at 6, 8, 10, and 12 breaths per minute each in a supine, sitting and standing position. Beat-to-beat RR-intervals and systolic pressure levels were calculated from raw ECG and Finapres signals. The time offset between positive RR-interval changes and subsequent negative systolic pressure level changes was calculated by cross correlation. Baroreflex sensitivity was calculated from the frequency domain of RR-interval and systolic pressure levels changes, using the ratio of the height of the peaks at each breathing frequency.

Time offset significantly decreased by 1.83 ± 0.69 s (mean ± SD) ($p<0.001$) when breathing rate increased from 6 to 12 breaths per minute. Posture had no influence. Baroreflex sensitivity decreased by 20.1 ± 18.5 ms/mmHg (mean ± SD) ($p<0.01$) as posture changed from supine to standing, but was independent of breathing frequency.

Posture and breathing frequency are two factors of many that can influence baroreflex measures. These preliminary results show that a better understanding of their effects is needed to allow repeatable measurement protocols to be developed.

1. Introduction

Baroreflex sensitivity (BRS) measurements have been shown to be clinically useful, especially in determining prognosis after myocardial infarction [1]. The National Insitute of Clinical Excellence (NICE) has also recommended measuring BRS when determining suitability of patients to receive implantable cardioverters [2]. The main reason that baroreflex measures are not in widespread use is due to their poor repeatability [3].

We would like to improve the repeatability of BRS and the lesser-used parameter time offset between changes in RR interval and changes in systolic pressure levels. We intend doing this by looking at different influences to both parameters. This study assessed the influences of posture and breathing frequency on these baroreflex measurements.

2. Methods

Six normal healthy volunteers (2 female, 4 male) with a mean age of 32 years (standard deviation 12 years), mean resting heart rate of 61 beats per minute (standard deviation 8 beats per minute) and mean systolic pressure of 128 mmHg (standard deviation 25 mmHg) breathed regularly by following a scrolling triangular waveform on an oscilloscope at 6, 8, 10, and 12 breaths per minute each in a supine, sitting and standing position. In each case a single lead ECG and non-invasive continuous blood pressure (Finapres) signals were recorded to computer.

Beat-to-beat RR-intervals and systolic pressure levels were calculated by dedicated software off-line and manually checked. A linear interpolation algorithm [4] was used to convert the RR intervals and systolic pressure levels from beat numbers to regularly sampled time elements (16 Hz).

BRS was calculated from the frequency domain of the final 150 s of the regularly sampled RR-interval and systolic pressure levels changes. The ratio of the height of the peaks at each breathing frequency represented BRS.

The regularly sampled data sets were also bandpass filtered, the filter being centred at the breathing frequency. The first sixty seconds of both filtered data sets were discarded because the body needed time to acclimatise to the regular changes. The average time offsets between the RR-interval signal and blood pressure level signal were calculated using the Pearson cross correlation function [5]. The position of the minimas and maximas of the correlated signal depicted the time points when the RR-interval signal and systolic pressure level signal were either 180° out of phase or in phase and hence represented time offsets between the two signals. The position of the minima after the zero offset represented the time offset between positive RR-interval changes and subsequent negative systolic pressure level changes.

The processes described are summarised in figure 1.

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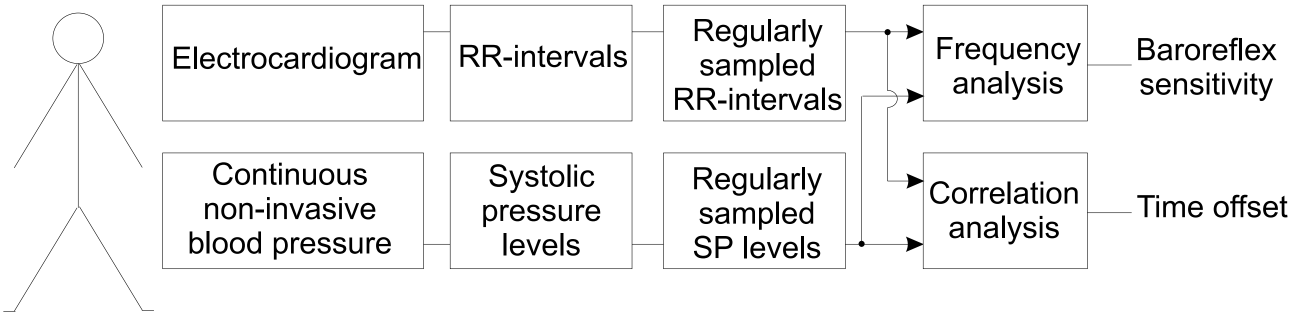

Figure 1. Processes used to calculate baroreflex sensitivity and time offset.

An analysis of variance was performed to look for consistent effects with changes in posture and breathing frequency. The combinations from this analysis that were significant were explored further with paired t-tests.

3. Results

Figure 2 shows typical results from one subject in a fixed posture but with variable breathing rates. RR-intervals and systolic pressure levels changed with inspiration and expiration. Only 60 s of data was displayed in the time domain, but 150 s of data was used to calculate the frequency domain. Consequently the baseline wander of the systolic pressure signal is more apparent in the frequency domain in the appearance of low frequency components than in the time domain section. The heights of both peaks in the frequency domain reduced with increasing breathing rate in the same way, so BRS remained fairly constant across breathing frequency. With this subject there was less variation than would be expected for systolic pressure levels at 8 breaths per minute. These occasional variations from the trend appeared common across all subjects. The time offset reduced with increasing breathing frequency

Figure 3 shows typical results from one subject breathing at a fixed breathing rate but in a variety of postures. Again RR-intervals and systolic pressure levels changed with inspiration and expiration. Due to a short time period being displayed and the longer time period used to calculate the frequency domain, again the baseline wander of the systolic pressure signal is more apparent in the frequency domain than in the time domain section. The heights of the RR-interval peaks in the frequency domain remained constant regardless of posture. Whereas systolic pressure level peaks increased with a more upright posture and hence baroreflex sensitivity reduced with a more upright posture. The time offset remained fairly constant despite the change in posture.

When looking at all the data baroreflex sensitivity could be calculated for 94% of the recordings; occasionally systolic pressure levels or RR-intervals did not vary with the respiration signal so a ratio could not be

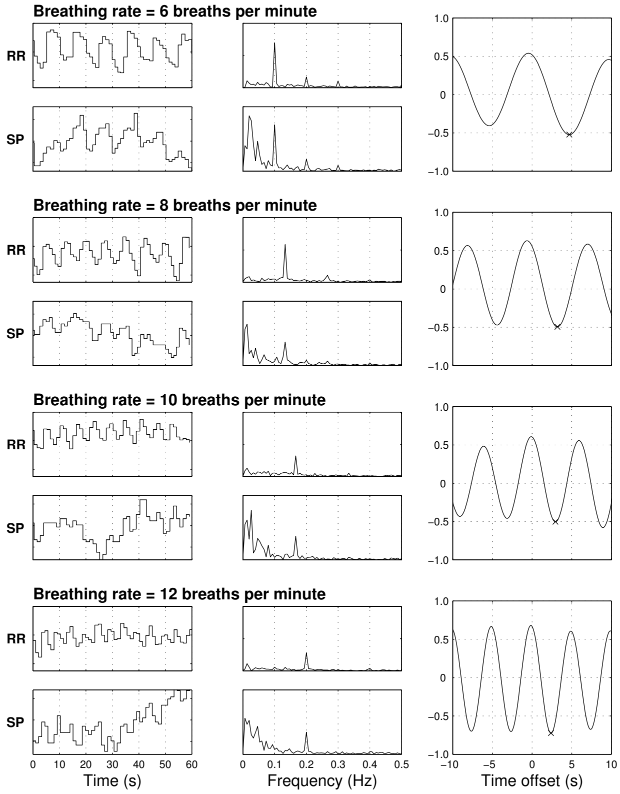

Figure 2. Typical results from one subject in a supine position, breathing at different frequencies. First, second and third columns shows 60 s of RR-interval and SP level data; frequency spectra for the RR-interval and SP level data; and the correlation signal that results when the two filtered signals are correlated against each other, respectively. The y-axis is consistent for each graph type; RR-interval in the time domain, range is 450 ms; RR-interval in the frequency domain is 0 to 200 × 10^3 ms; SP levels in the time domain, range is 15 mmHg; and SP levels in the frequency domain is 0 to 5000 mmHg. The y-axis on the correlation signal is the pearson cross correlation coefficient. The BRS is 39, 64, 35 and 32 ms/mmHg and time offset is 4.69, 3.19, 2.94 and 2.38 s for 6, 8, 10 and 12 breaths per min respectively.

determined. As figure 4 shows, BRS reduced by 20.1 ± 18.5 ms/mmHg ($p<0.01$) when the posture changed from supine to standing. A significant difference between supine to sitting was noted, but there was no significant difference between sitting and standing. Figure 4 also shows that there was no significant difference in baroreflex sensitivity with breathing rate.

Time offset could be calculated for 89% of the recordings; the correlation signals of the remaining data were not periodic. Figure 4 shows that time offset significantly decreased by 1.83 ± 0.69 s ($p<0.001$) when breathing rate increased from 6 to 12 breaths per minute. The mean time offsets for the intermediate breathing rates changed linearly. Figure 4 also shows that posture had no influence on the time offset.

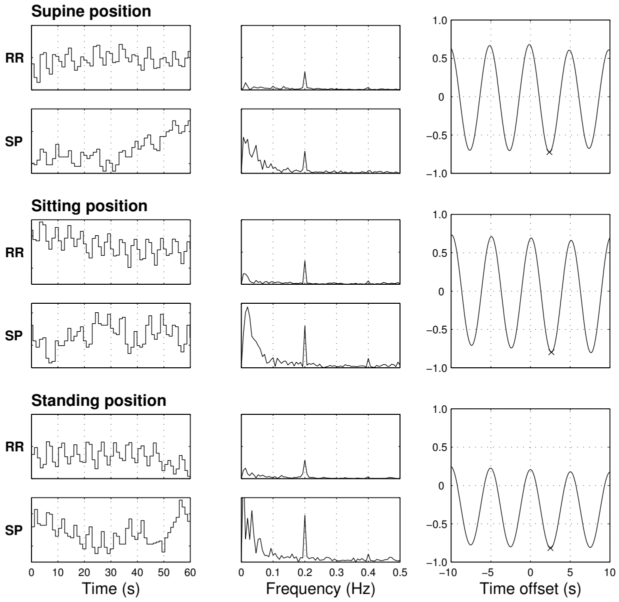

Figure 3. Typical results from one subject breathing at 12 breaths per minute, in a supine, sitting and standing position. First, second and third columns shows 60 s of RR-interval and SP level data; frequency spectra for the RR-interval and SP level data; and the correlation signal that results when the two filtered signals are correlated against each other, respectively. The y-axis is consistent for each graph type; RR-interval in the time domain, range is 450 ms; RR-interval in the frequency domain is 0 to 200×10^3 ms; SP levels in the time domain, range is 20 mmHg; and SP levels in the frequency domain is 0 to 5000 mmHg. The y-axis on the correlation signal is the pearson cross correlation coefficient. The baroreflex sensitivity is 32, 22, and 16 ms/mmHg and time offset is 2.38, 2.63 and 2.50 s for supine, sitting and standing respectively.

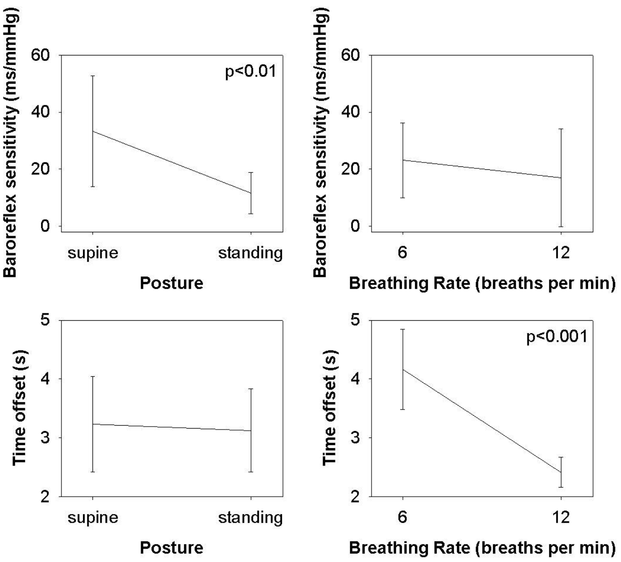

Figure 4. Graphs showing the effect of posture and breathing frequency on time offset and baroreflex sensitivity.

4. Discussion and conclusions

A similar effect of posture on baroreflex sensitivity has been observed by Iellamo et al [6]. Iellamo et al also suggested that recording BRS in a standing position was more repeatable than in a supine position. We certainly found inter-subject variability less in a standing position. Saul et al [7] did not look directly at BRS, but looked at the magnitude of the cross spectrum of heart rate and blood pressure, and so the units were in bpm/mmHg. Nevertheless they showed that the magnitude reduced between supine and standing postures.

Saul et al also showed that the phase between heart rate and blood pressure was constant regardless of posture. Nevertheless Zhao et al [8] showed that there was an offset dependent on posture with normal subjects. Our results agree with Saul's findings. Pitzalis et al [9] showed that time offset reduces with increasing breathing rate.

Posture and breathing frequency are two factors of many that can influence baroreflex measures. These preliminary results show that a better understanding of their effects is needed to allow repeatable measurement protocols to be developed.

Baroreflex sensitivity has been measured since 1969. This study shows that we still need to understand what factors influence the measurement. Breathing frequency strongly influenced the time offset, and posture strongly influenced baroreflex sensitivity.

Acknowledgements

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Address for correspondence.

Emma J. Bowers
Regional Medical Physics Department
Freeman Hospital
High Heaton
Newcastle upon Tyne
NE7 7DN
UK

emma.bowers@nuth.northy.nhs.uk