Temporal Changes in Complexity of Cardiovascular Regulation during Head-up Tilt Test by Entropic Measures of Fluctuations of Heart Period Intervals and Systolic Blood Pressure

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Abstract—Dynamical aspects of cardiovascular regulation in the head-up tilt test are revealed through the properties of the approximate entropy and sample entropy of increments between subsequent heart period intervals and increments between subsequent systolic blood pressure values. Marked differences are observed in the dynamical response to the tilt test of healthy subjects prone to spontaneous fainting and those who are less susceptible to fainting.

I. INTRODUCTION

Several physiological mechanisms are involved in maintaining efficient cardiovascular provision for the organism’s needs. Changes in the systolic blood pressure (SBP), sensed by baroreceptors, induce changes in the time intervals between two consecutive heart contractions (RR-intervals) through the baroreflex. In turn the length of the RR-interval affects SBP according to Starling’s law and the arterial Windkessel.

The head-up tilt (HUT) test is a valuable tool for the evaluation of susceptibility to vasovagal syncope [1], [2]. The test is dynamic and therefore demands a dynamical assessment of changes in the cardiovascular system. In particular, observation of the development of vasovagal syncope could provide valuable insights into the phenomenon of cardiovascular regulation.

In this context, fluctuations in the simultaneous recordings of RR-intervals and SBP obtained through the HUT test, divided into five-minute window segments, see Fig. 1, are investigated by the popular nonlinear tools which measure the complexity of time series: approximate entropy (ApEn) [3] and sample entropy (SampEn) [4].

The results presented are preliminary. They are a starting point for our ongoing investigations aiming at the elucidation of complex interactions in the cardiovascular system.

II. METHODS

A. Group description and signal preprocessing

Fifty healthy volunteers with no history of fainting were included in the study. The HUT tests were performed in the same ambulatory conditions and with the same rigor of paced of breathing (15 breaths per minute). Details of the HUT test protocol are described in the caption to Fig. 1. Depending on the test outcome: he/she did not faint or he/she did faint, each subject was respectively classified as either NEG or POS. Surface ECG (lead II) and beat-to-beat blood pressure were recorded simultaneously, using the Task Force Monitor system. Five recordings were excluded from the further analysis because of bad quality (large periods with missing SBP values). There were no abnormal heart beats. Single missing values in signals with SBP were filled by the median calculated from seven correct values surrounding the defect.

Finally, 32 signals were accepted for the NEG group and 13 signals from the POS group. All the subjects in the POS group fainted during the active test.

In addition to the signals with RR-intervals (denoted RR) and SBP, the signals of differences were studied, i.e.,
\[ \Delta RR(i) = RR(i) - RR(i-1) \] and \[ \Delta SBP(i) = SBP(i) - SBP(i-1) \]. \textit{ApEn} and \textit{SampEn} were calculated for each person, for every 5-minute time segment: \textbf{H00}, \textbf{P00}, \textbf{P05} and \textbf{P10}, and for all signals: $RR$, $\Delta RR$, $SBP$ and $\Delta SBP$. We used $m = 2$, and $r = 0.2SD$ in estimates of entropies.

III. RESULTS

The basic time domain indices of heart rate variability (HRV) and blood pressure variability (BPV), such as the mean and standard deviation, are presented in Fig.2.

Mean $RR$ decreases significantly when moving from the supine to the upright position. However, while in the case of \textit{NEG} group this lower value does not change over time, in the case of the \textit{POS} group a slight further decrease is observed. The opposite relation describes properties of the mean SBP.

The values of entropies collected in groups \textit{NEG} and \textit{POS} in most cases do not pass the normality test. Therefore in Figs 3 and 4, we represent \textit{ApEn} and \textit{SampEn} by the medians.

We see that: (1) the values of both entropies change over time, which justifies our method of time segmentation; (2) while the values of \textit{ApEn} for signals of increments are only slightly greater than the values of the corresponding signals, in the case of \textit{SampEn} this difference is large (around 0.5), which indicates a significant difference in randomness between signals and their derivatives; (3) both entropies decrease for $RR$s after the change in position, however opposite changes are observed for entropies of $SBP$ signals; (4) it is not surprising that the differences between \textit{NEG} and \textit{POS} are not significant. Both groups consisted of healthy people with no signs or symptoms of cardiovascular disorder. Nevertheless, some of them fainted during the test. Statistically significant differences (the Mann-Whitney U test with $P < 0.1$) are obtained in \textbf{P05} for entropies of ($\Delta RR$), and in \textbf{P10} for \textit{ApEn}(\textit{$\Delta SBP$}).

IV. CONCLUSIONS

\textit{ApEn} and \textit{SampEn} of heart rate and blood pressure increments provide additional information differentiating healthy people prone to spontaneous fainting from those who are less susceptible to fainting.

REFERENCES