Changes in sympathetic modulation of ECG repolarization associated with long-term microgravity exposure

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1. Background

After a long period of exposition to microgravity, astronauts present alterations in the cardiovascular system, including orthostatic intolerance. Dysregulation of autonomic modulation might be an important contributor.

Recent studies have proposed quantification of Periodic Repolarization Dynamics (PRD) to assess sympathetic modulation of ventricular repolarization. PRD quantifies low-frequency (≤0.1 Hz) periodic components in the spatial orientation of the T wave, which represents ventricular repolarization in the electrocardiogram (ECG) [1].

In this study we evaluate PRD as an index to quantify the effect of simulated microgravity in the sympathetic nerve control of cardiac electrical activity.

2. Materials and Methods

ECGs from 22 male subjects, enrolled in a long-term duration (60 days) head-down bed-rest (HDBR) campaign were available for the analysis. The whole group was randomly distributed into two groups: a counter-measure group (JUMP), who exercised on a sledge jump system [2], and a control group (CTRL) who did not do that exercise.

The ECG signals recorded during a tilt test before (PRE) and after (POST) the bed rest period were preprocessed and T wave onsets and end were determined using a single-lead wavelet-based delineator. The tilt test included: 15 min tilted head-up to an angle of 80º and subsequent return.

To compute the PRD index [2], the 12-lead ECG was converted into orthogonal X, Y, Z leads, which were subsequently transformed into polar coordinates. For each beat, the weight-averaged azimuth (WAA) and weight-averaged elevation (WAE) were computed, describing the average direction of repolarization. A beat-to-beat series of angles, dTº, was calculated, where dTº is the angle between two consecutive T-waves (using WAA and WAE). A median filter was applied to the resulting series to discard outliers and the filtered series were then interpolated, converting it into 2-Hz evenly sampled sequences.

The continuous wavelet transform (using a fourth-order Gaussian function as the mother wavelet) was applied to perform spectral analysis of the interpolated angle series, defining the PRD as the average of the wavelet coefficients corresponding to pseudo-frequencies from 0.025 to 0.1 Hz.

3. Results

In the ECG signals recorded before microgravity exposure, the onset of the tilt test led to a large increase in median PRD values, which changed from 1.9850 deg^2 (interquartile range, IQR, 2.0165 deg^2) at baseline to 3.1599 deg^2 (IQR 3.4906 deg^2) at the beginning of tilt. PRD values at the end of the tilt test returned to baseline ranges, with the median being 1.8026 deg^2 (IQR 2.5722 deg^2). Differences were not statistically significant in any case, which might be attributed to the low number of samples. The obtained results help to support the idea of PRD being a reflection of sympathetic modulation of ventricular repolarization.

Microgravity induced increases in PRD values either when measured at baseline or at the onset or end of the tilt test. Changes in median PRD were from 2.0488 deg^2 (IQR 1.1788) for PRE to 2.6956 deg^2 (IQR 3.2132 deg^2) for POST at baseline, from 2.3867 deg^2 (IQR 3.3161 deg^2) to 4.2480 deg^2 (IQR 6.4571 deg^2) at the onset of the tilt and from 2.2797 deg^2 (IQR 30681 deg^2) to 2.7978 deg^2 (IQR 3.4680 deg^2) at the end of the tilt. A statistically significant difference is found at the baseline ($p = 0.0497$). However, the difference is not significant during the onset ($p = 0.09$) or end of the tilt ($p = 0.47$).

No statistically significant differences were found between the CTRL group and JUMP group neither during PRE nor POST.

4. Conclusions

Simulated microgravity affects sympathetic modulation of ventricular repolarization (T-wave) and is detected by quantification of low-frequency oscillations in T wave orientation. The tested countermeasure is not effective in reducing the effects of microgravity on T-wave oscillations.

References

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