CARDIOVASCULAR EFFECTS OF SIMULATED MICROGRAVITY

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INTRODUCTION

Impaired cardiovascular response to orthostatic stress after space flight and the occurrence of serious cardiac dysrhythmias during space flight are among critical cardiovascular risks associated with space flight as specified by the critical path road map. The development of postflight orthostatic intolerance (OI) is very well documented. However, the exact mechanism underlying this phenomenon is unclear. The most pressing research question with respect to the issue of cardiac dysrhythmias is to determine whether space flight does indeed increase the risk of life threatening ventricular tachyarrhythmias and, if so, what mechanisms may be involved and what effective countermeasures may be applied. In this abstract, we evaluate 1) the effect of 14 to 16 day head-down-tilt bed rest (simulated microgravity) on a clinically used index of ventricular electrical stability (microvolt T-wave alternans - MTWA) and OI. With respect to OI we specifically examine effects of gender, autonomic function and calf venous compliance and vascular resistance.

METHODS

We employed a newly developed technique for quantifying parasympathetic and sympathetic responsiveness by analyzing the heart rate fluctuations due to respiration (Respiratory Sinus Arrhythmia) [1]. This technique extracts parameters to represent parasympathetic and sympathetic responsiveness from analysis of the coupling between instantaneous lung volume (ILV) and heart rate (HR) while holding other parameters (e.g. blood pressure) constant. We calculated calf venous compliance and vascular resistance utilizing a model-based analysis of venous occlusion plethysmography data [2]. Thigh-cuff pressures of 30, 40, and 50 mmHg were applied consecutively while mercury-in-silastic strain gauge was employed to measure the changes in leg circumference. Non-invasive microvolt T-wave alternans (MTWA) testing was conducted using CH-2000™ (Cambridge Heart, Inc., Bedford, MA) instrumentation during bicycle exercise (the CH-2000™ utilizes the spectral analytic method for detecting MTWA which was developed in our laboratory). We defined, for the purposes of this study, an MTWA test as positive if sustained alternans developed with an onset heart rate \( \leq 125 \text{ bpm} \); sustained alternans is considered positive for clinical purposes only if the onset heart rate \( \leq 110 \text{ bpm} \). We studied 29 male subjects and 14 female subjects.

RESULTS

Our results showed that: 1) Prior to bed rest 17% of male subjects were positive; after bed rest 42% were positive, \( p = 0.03 \) 2) 66% of 29 male subjects tolerated the tilt test pre-bed rest, 36% tolerated the tilt test at the end of bed rest (pre vs. end \( p = 0.037 \)), while 83% tolerated the test after 2 days of recovery post-bed rest (pre vs. post \( p = 0.23 \); end vs. post \( p = 0.0009 \)); 2) both parasympathetic and sympathetic responsiveness were reduced significantly after bed rest in the male subjects (\( p = 0.02, p = 0.02 \) respectively); 3) Male subjects with OI pre-bed rest had a smaller sympathetic responsiveness (\( p = 0.01 \)) and a larger parasympathetic responsiveness (\( p = 0.02 \)) than non-OI subjects and the autonomic responsiveness at baseline relates to OI after bed rest (parasympathetic: \( p = 0.01 \), sympathetic \( p = 0.02 \)); 4) the leg compliance increased significantly after bed rest (\( p = 0.037 \)) and the subjects who were tilt tolerant before bed rest had significantly higher pre-bed rest calf compliance (\( p = 0.008 \)) and higher vascular resistance (\( p = 0.03 \)) than the tilt-intolerant subjects. After bed rest, no such difference was found between tilt tolerant and intolerant subjects; 5) the female subjects had a significantly higher incidence of OI than the male subjects pre-bed rest (\( p = 0.005 \)) and none of them tolerated tilt test after bed rest; 6) the females subjects had a higher parasympathetic responsiveness and a lower sympathetic responsiveness than the male subjects at baseline.

DISCUSSION

Sixteen days of head down tilt bed rest increases the incidence of MTWA at a subclinical level.

Based on our data, we hypothesize that higher calf compliance at baseline, as a result of the postural stresses of daily ambulation, leads to recruitment of compensatory mechanisms (as manifested by enhanced sympathetic function and increased vascular resistance during venous occlusion) resulting a better toleration of orthostatic stress. With the absence of orthostatic challenge during prolonged bed rest, the difference in calf hemodynamic parameters is attenuated between the tilt tolerant and intolerant groups.