

DETECTION AND PREVENTION OF CARDIAC ARRHYTHMIAS DURING SPACE FLIGHT

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There have been reports suggesting that long-duration space flight might lead to an increased risk of potentially serious heart rhythm disturbances. If space flight does, in fact, significantly decrease cardiac electrical stability, the effects could be catastrophic, potentially leading to sudden cardiac death. It will be important to determine the mechanisms underlying this phenomenon in order to prepare for long-term manned lunar and interplanetary missions and to develop appropriate countermeasures.

Electrical alternans affecting the ST segment and T-wave have been demonstrated to be common among patients at increased risk for ventricular arrhythmias. Subtle electrical alternans on the ECG may serve as a noninvasive marker of vulnerability to ventricular arrhythmias. We are studying indices of electrical instability in the heart for long term space missions by non-invasively measuring microvolt level T-wave alternans in a reduced gravity environment. In this investigation we are using volunteer subjects on the KC-135 aircraft as an initial study of the effect of electrical adaptation of the heart to microgravity. T-wave alternans will be analyzed for heart rate variability and QT restitution curve plotting will be compared for statistical significance.

Our hypothesis is that prolonged exposure to microgravity will alter T wave alternans measurements, decrease heart rate variance, increase QT dispersion, decrease heart rate recovery and alter QT restitution curve. A recently published study has shown that long duration spaceflights prolong cardiac conduction and repolarization. They concluded that long duration flight is associated with QT interval prolongation and may increase arrhythmia susceptibility. We propose using computer technology as a noninvasive clinical tool to detect and study clinically significant TWA during standard exercise testing using electrode systems specifically adapted for the purpose of obtaining and measuring TWA.

The equipment we will use for this operational and follow-on biomedical testing is the FDA approved Cambridge Heart Heartwave Diagnostic System modified to use a laptop computer versus a desktop unit developed for a hospital lab setting. The unique features of this ECG unit are the microvolt sensitivity, the back lead which is used to derive 3D electrical vectors of the heart, and the proprietary Cambridge Heart analysis and display software. The unit measures microvolt T-wave alternans using seven proprietary micro-V alternans sensors and seven standard electrodes placed in the standard 12-lead configuration, as well as four Frank vector positions. The micro-V sensors reduce the effects of muscle noise and baseline wander when used in conjunction with specialized signal processing techniques.

Protocols will be observed for preflight, in-flight, postflight and KC-135 flight data collection. The KC-135 flights will help with early operational research testing techniques. The purpose of the operational experiment is to correlate cardiac parameters with blood pressure and gravity levels to determine how the data fits historical ground data. The complete experiment has both operational and biomedical research component. IRB approval of the study will be obtained. Informed consent will be obtained from the participants.

The T wave alternans test results can be positive, negative or indeterminate. The test has an excellent negative predictive value and therefore, those who test negative are at a low risk for sudden cardiac death. Those who test positive may be at risk of susceptibility to ventricular arrhythmias. A statistical analysis of the land-based, low gravity, Martian trajectory and Lunar trajectory environment measurements will be made and determined if there is any significant difference between the recordings.

A population of approximately 15 healthy men and 5 healthy women subjects, representative of the astronaut cohort will be asked to voluntarily participate in this study. Their blood pressure and ECG/TWA will be measured pre-flight and in-flight. Prior to flight, subjects will be asked to participate in an orientation session. Still photos will be taken of the skin where the conductive gel is used for the multi-segment sensors. Photos will be recorded preflight, immediately postflight, and several times during the proceeding week until it has been determined that any skin reaction has disappeared or that no rash is present and will not appear.

A Fast Fourier Transform (FFT) spectral analysis uses the vector magnitude ECG signal recorded from three orthogonal leads over a predetermined minimum number of ECG beats. The analysis yields two measurements: the alternans magnitude and alternans ratio. These are obtained using the Cambridge Heart CH2000 Cardiac Diagnostic System instrument. A positive T-Wave alternans test is the presence of sustained alternans with an amplitude at least 1.9 microvolt and alternans ratio of ≥ 3.0 . A quantitative analysis of this data will be performed and presented in a chart form listing each subject's (no name, just subject's number) systemic blood pressure and ECG for pre-flight and in-flight. This data will be compared with ground-based studies and used to develop further medical protocols and possible countermeasures.

The goal of this research is to perform operational testing in low gravity of an advanced ECG with microvolt resolution and 3D localized features to account for altered heart position associated with the low gravity environment of space. Once operational feasibility is proven medical protocols will be developed to determine if advanced ECG testing (including T-wave alterations and Q-T dispersions) can be performed in low gravity. The purpose of the operational experiment is to correlate cardiac parameters with blood pressure and gravity levels to determine how the data fits historical ground data. The complete experiment has both operational and biomedical research component. The first flight week, May 17, 2004, will be operational testing. A research plan will be developed for testing beginning on the August 2, 2004 flight week. An early operational and research objective will be to determine if a series of TWA tests of 20-40 seconds (30-60 beats) can be correlated to produce the same result as one consecutive 128 beat test.