Detection and Prevention of Arrhythmias during Space Flight

Dilip Pillai‡, David Rosenbaum‡, Kathy Liszka†, David York§, Michael Mackin§, Michael Lichter§, 

‡MetroHealth Campus, Case Western Reserve University, 
†The University of Akron, 
§NASA Glenn Research Center.
Introduction

- Effects of prolonged microgravity on the electrical stability of the heart are unknown.
- Documented ventricular arrhythmias in Russian and US space programs.
- Structural remodeling of the heart in microgravity may predispose to arrhythmia.
- Fatal arrhythmias could be the first presentation of underlying cardiac disease.
**Diagram of an ECG Waveform**

**Vertical Axis**
- 1 Small Square = 1 mm (0.1 mV)
- 1 Large Square = 5 mm (0.5 mV)
- 2 Large Squares = 1 mV

**Horizontal Axis**
- 1 Small Square = 0.04 sec (40 m sec)
- 1 Large Square = 0.2 sec (200 m sec)
- 5 Large Squares = 1 sec (1000 m sec)

- P-R Interval
- Q-T Interval
- ORS Duration

- P
- Q
- R
- S
- T
- U
An Episode of Ventricular Tachycardia during Long-duration Spaceflight

Cardiac atrophy after space-flight

Effect of short and long duration spaceflight on QTc intervals in Healthy Astronauts

Indices of electrical instability in the heart

- Microvolt T wave alternans
- QT restitution curve
- Heart rate variability
- Heart rate recovery after exercise
Natural History Electrical Alternans?

Electrode Enhancement

Reduction of noise through adaptive cancellation of artifact

LL (Center)
LL (Segment)
LL Impedance
Respiration

Noise Reduction

LL Enhanced
T Wave Alternans Measurement

Electrocardiogram

T Wave Spectrum

Arrhythmia-Free Survival

Heart Rate Dependence of T Wave Alternans

QT INTERVAL RESTITUTION

Slope

QT INTERVAL

CYCLE LENGTH
POWER SPECTRAL ANALYSIS OF HRV

- LF vagal & symp.
- HF vagal eff with resp.
HEART RATE RECOVERY AFTER EXERCISE
relative risk of death within 6 years according to heart rate recovery

- decline of HR after exercise is a sign of vagal activation.
- a low recovery value has a negative predictive value of 95

Bicycle ergometer in space station
Study Aims

- Determine if orthogonal lead sets can correct artifactual ECG changes caused by microgravity-induced alterations in cardiac position.
- Determine if markers of susceptibility to SCD (TWA and QT restitution) can be reliably measured during space flight.
- Determine the effects of continuous microgravity on markers of susceptibility to SCD.
Methods: Exercise testing protocol

- Skin preparation
- ECG lead placement
- Activate CH2000 data acquisition system
- Exercise protocol (10 to 15 min)
  - 2.5 min recording during seated rest
  - 5 to 10 min exercise with progressive and gradual elevation of heart rate to 140 bpm
  - 2.5 min seated recovery
Study Protocol

- Sequential testing at baseline, then once monthly.
- Each test comprised of 32 channels of data, approximately 10 - 15 min duration (30 MB).
- Analysis off-line
  - Measure standard ECG intervals
  - Measure TWA as function of heart rate to determine heart-rate threshold for TWA.
  - Measure QT interval restitution during various stages of exercise
  - Calculate QT restitution slope
Anticipated Results

- Microvolt-level TWA and QT interval restitution can be reproducibly measured during space flight.
- Determine effects of continuous exposure to microgravity on TWA and QT interval restitution.
- Determine effects of autonomic dysregulation on these markers.
Conclusions

- Prolonged microgravity alters cardiac stability and may predispose to serious cardiac arrhythmias.
- Effect of microgravity on non-invasive markers of susceptibility to sudden cardiac death can be studied.
- Effective countermeasures and re-adaptive techniques can be deployed for prolonged space exploration.
THANK YOU.