Detection and Prevention of Arrhythmias during Space Flight

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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.
An Episode of Ventricular Tachycardia during Long-duration Spaceflight

Cardiac atrophy after space-flight


LV mass (g)

preflight
postflight
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


Alternans

Noise

FREQUENCY (cycles/beat)
Arrhythmia-Free Survival

TIME (Months)

PERCENT

Heart Rate Dependence of T Wave Alternans


![Graph showing heart rate dependence of T wave alternans](image-url)

- **Alternans (microvolts)**
  - Control
  - VT patient

- **Heart Rate (BPM)**
  - 80
  - 100
  - 120
  - 140
  - 160
QT INTERVAL RESTITUTION

QT INTERVAL vs CYCLE LENGTH

slope

a b c
POWERS SPECTRAL ANALYSIS OF HRV

LF vagal & symp.

HF vagal eff with resp

TP(0.04-0.50) = 59786

HF(0.15-0.50) = 15921
LF(0.04-0.15) = 43865
$\text{max}$(HF) = 1410
$\text{max}$(HF)[Hz] = 0.244
$\text{max}$(LF) = 6656
Fmax(LF)[Hz] = 0.122
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.