Detection and Prevention of Arrhythmias during Space Flight

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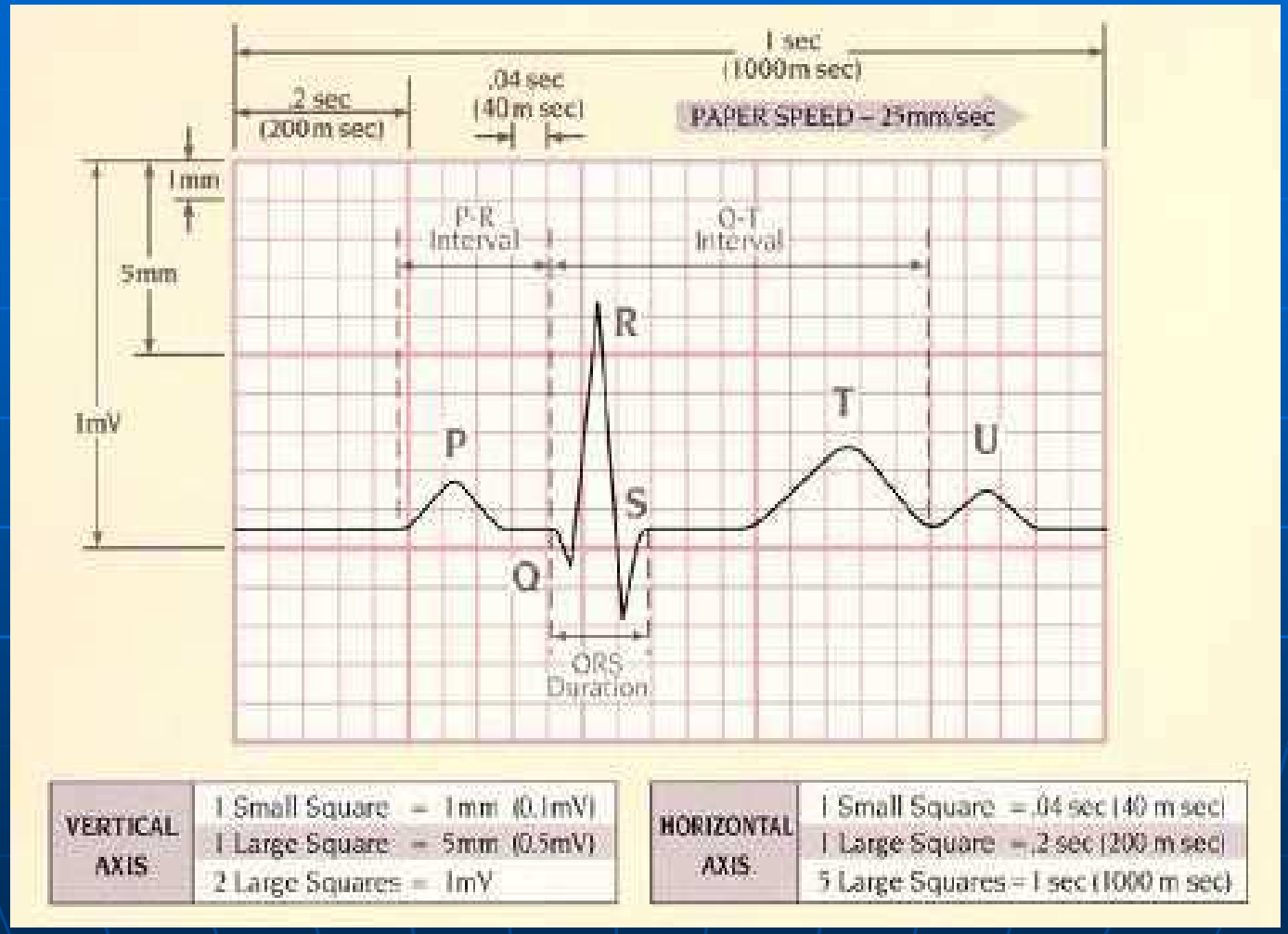
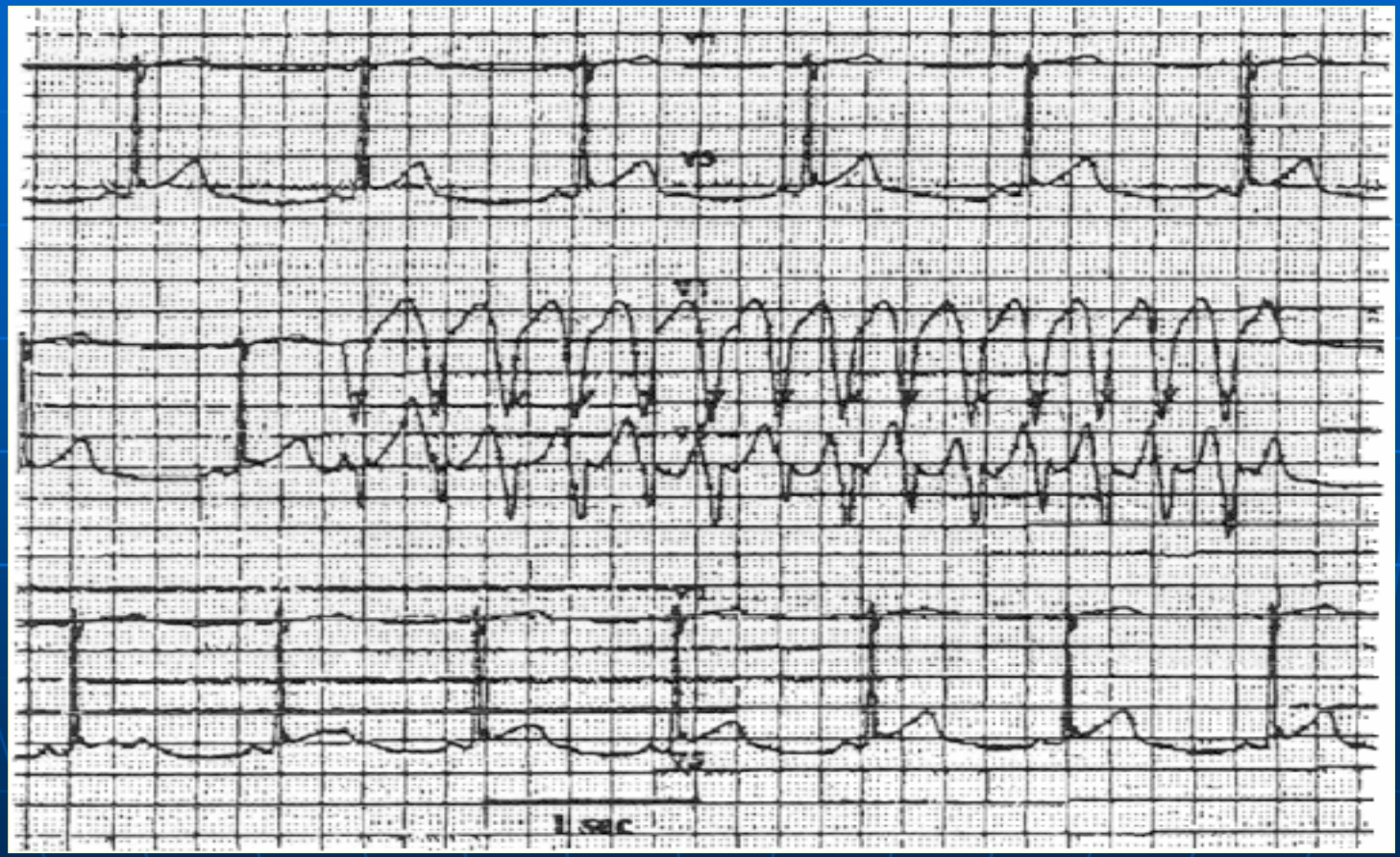
Introduction

- 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.


1 sec
(1000 m sec)
.2 sec
(200 m sec)
.04 sec
(40 m sec)
PAPER SPEED – 25mm/sec
1mm
5mm
1mV
P-R
Interval
Q-T
Interval
R
T
P
U
S
Q
QRS
Duration
VERTICAL AXIS
1 Small Square = 1mm (0.1mV)
1 Large Square = 5mm (0.5mV)
2 Large Squares = 1mV
HORIZONTAL AXIS
1 Small Square = .04 sec (40 m sec)
1 Large Square = .2 sec (200 m sec)
5 Large Squares = 1 sec (1000 m sec)

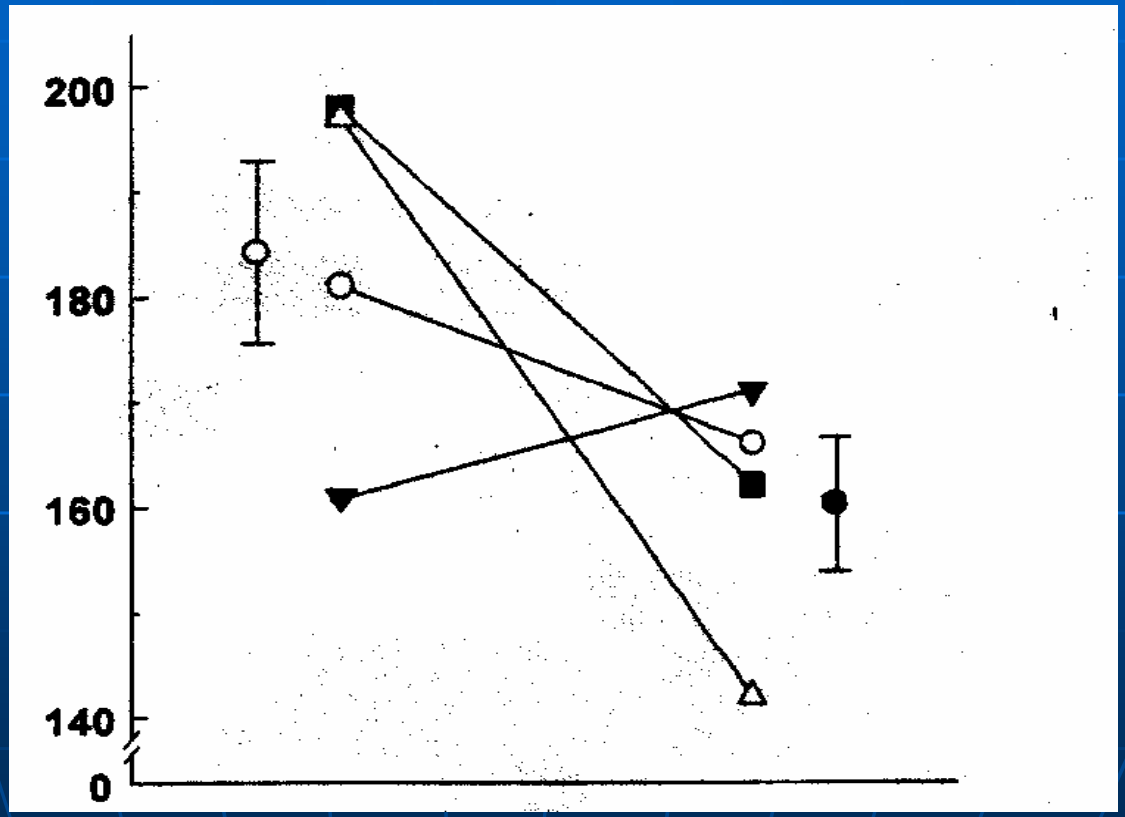
An Episode of Ventricular Tachycardia during Long-duration Spaceflight



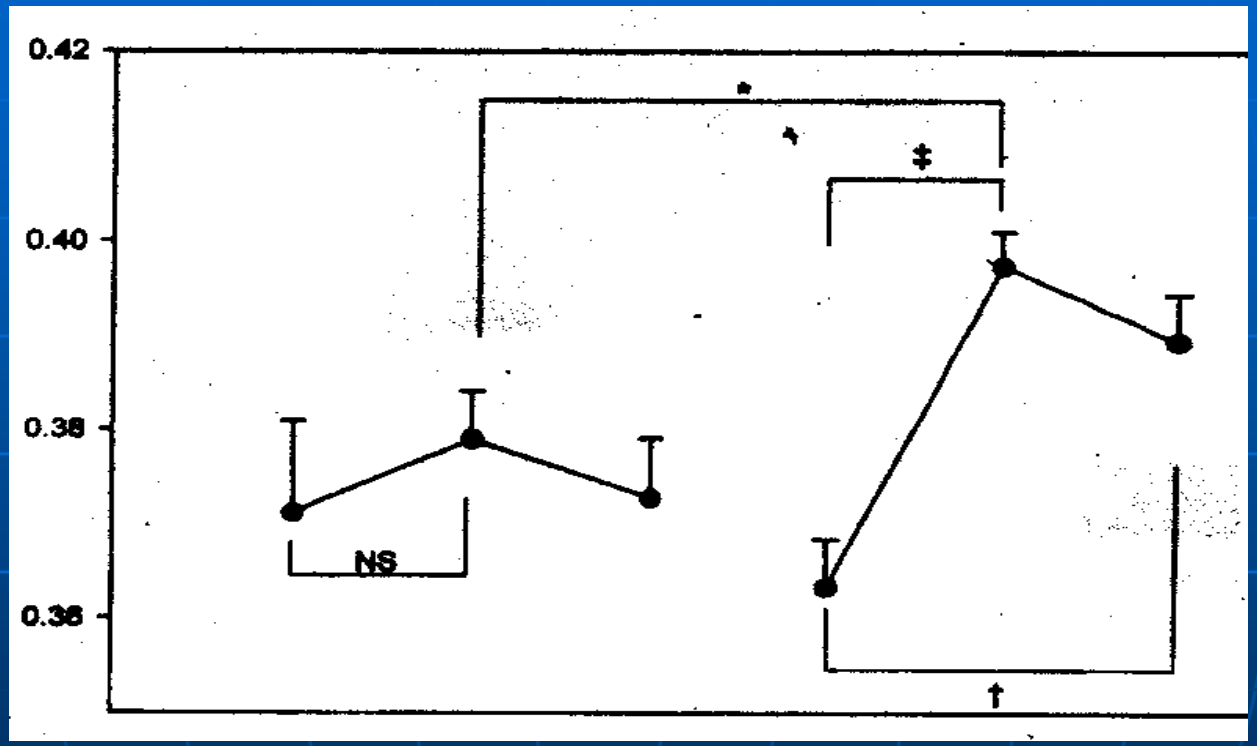
Fristch-Yelle JM et al. Am. J. Cardiol 1998;81:1391-2.

Cardiac atrophy after space-flight

Perhonen et al, J Appl Physiol 2001; 91:645-653.



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



QTc interval (sec)

A preflight
B landing
C postflight

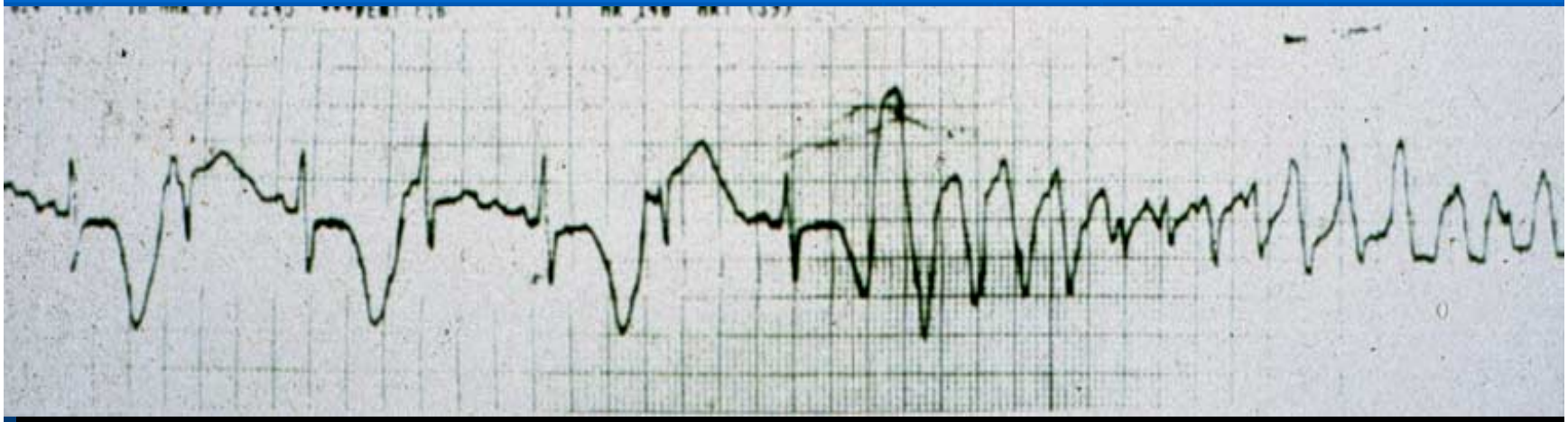
A B C A B C

D'Aunno DS et al. Am J Cardiol 2003;91:494-7.

Indices of electrical instability in the heart

- Microvolt T wave alternans
- QT restitution curve
- Heart rate variability
- Heart rate recovery after exercise

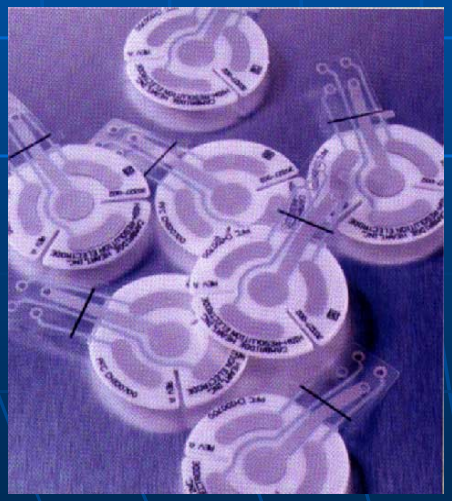
Natural History Electrical Alternans?

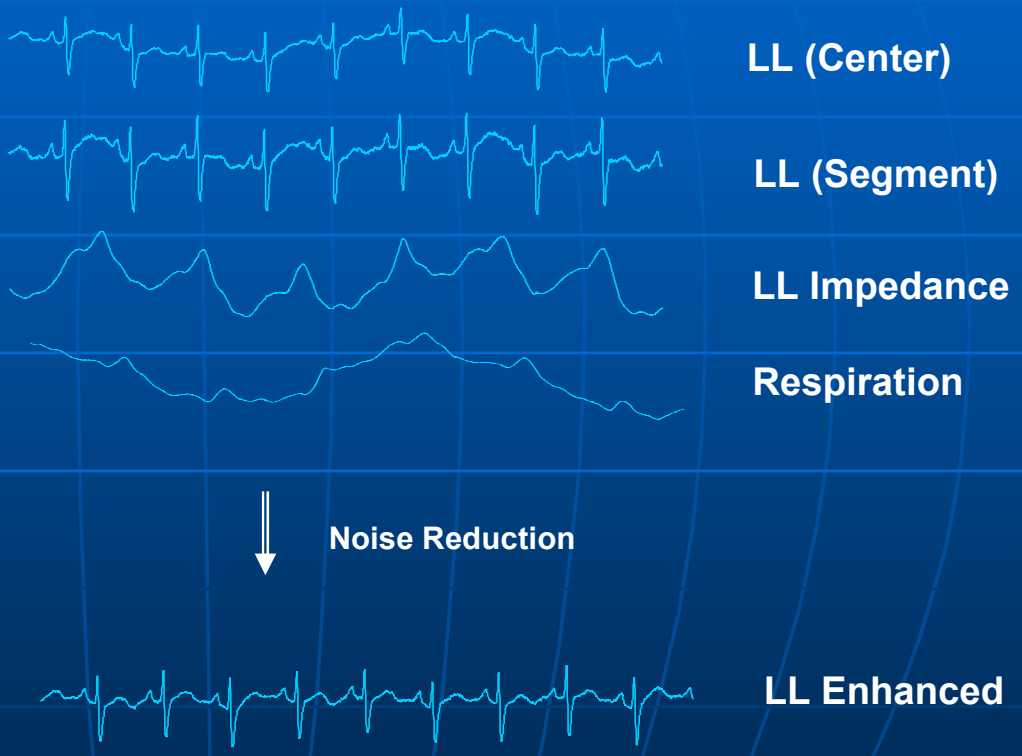


Raeder E, et al. N. Engl. J. Med 1992; 326: 272-73.

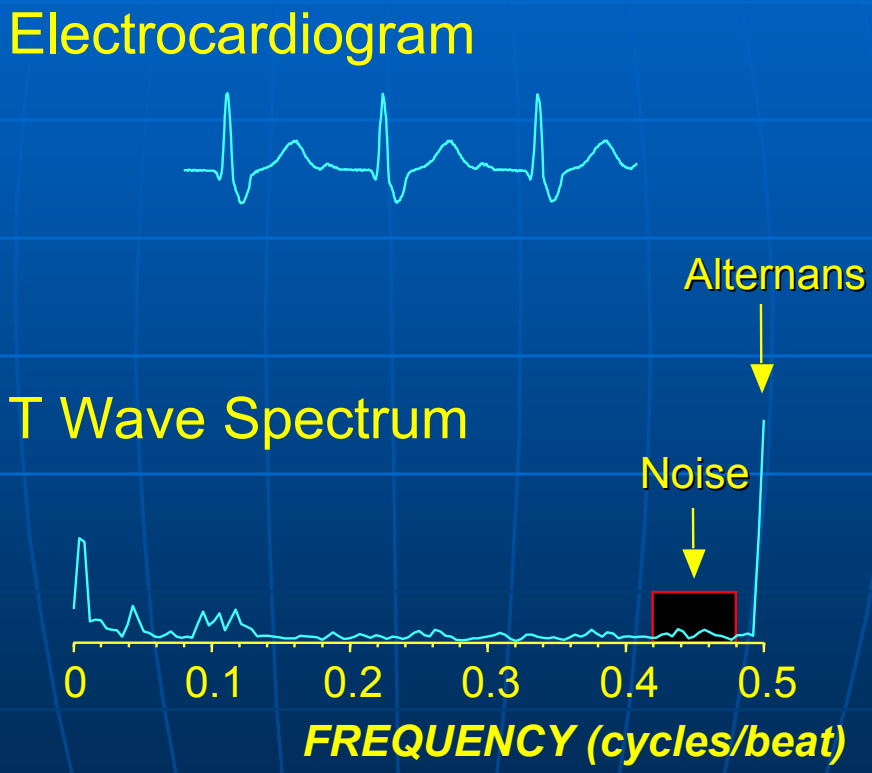
Electrode Enhancement

Reduction of noise through adaptive cancellation of artifact



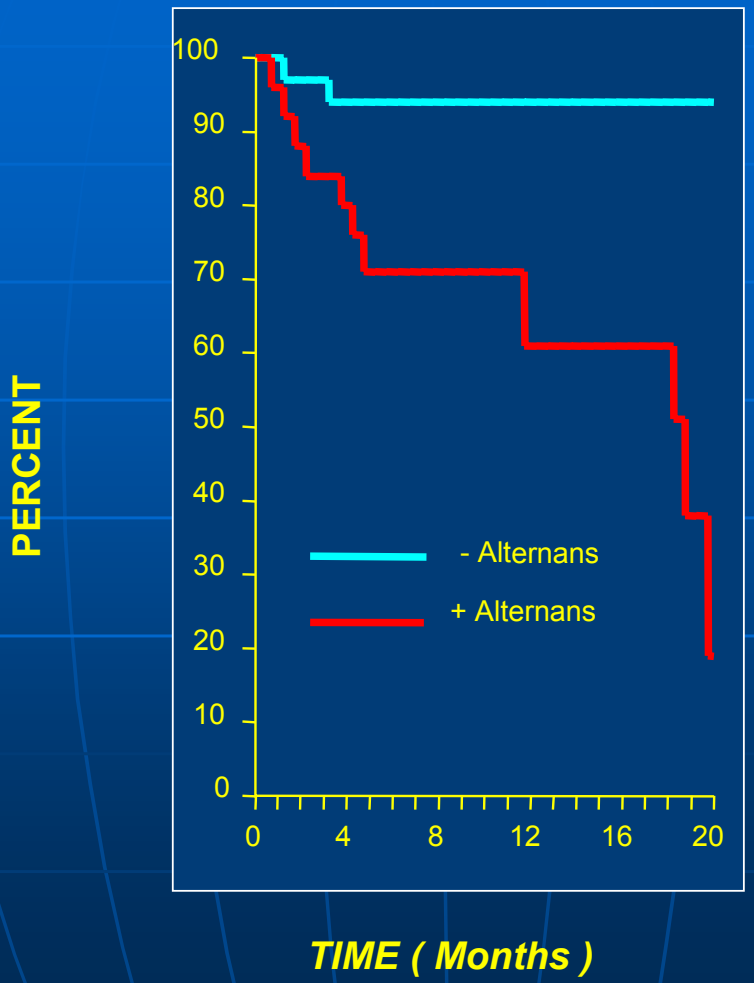


T Wave Alternans Measurement



Rosenbaum DS, et al. *N.Engl.J.Med.* 1994;330:235-241.

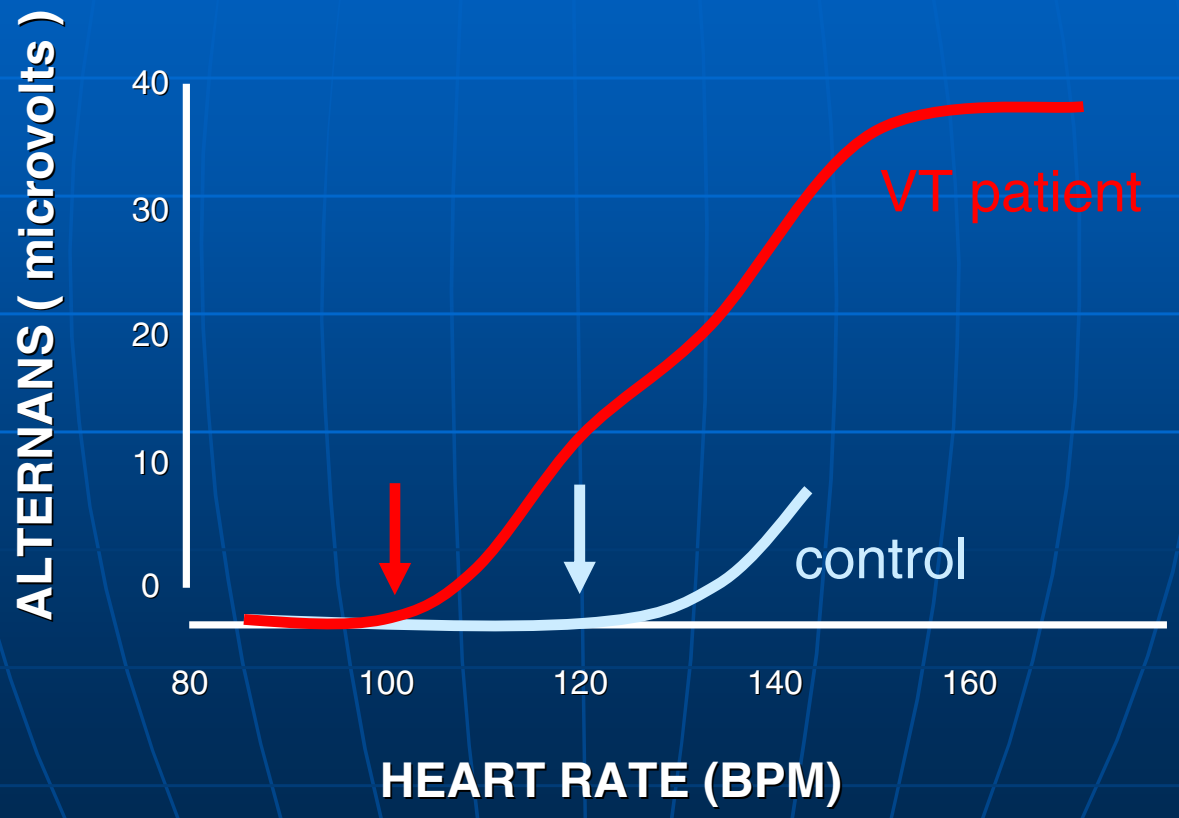
Arrhythmia-Free Survival

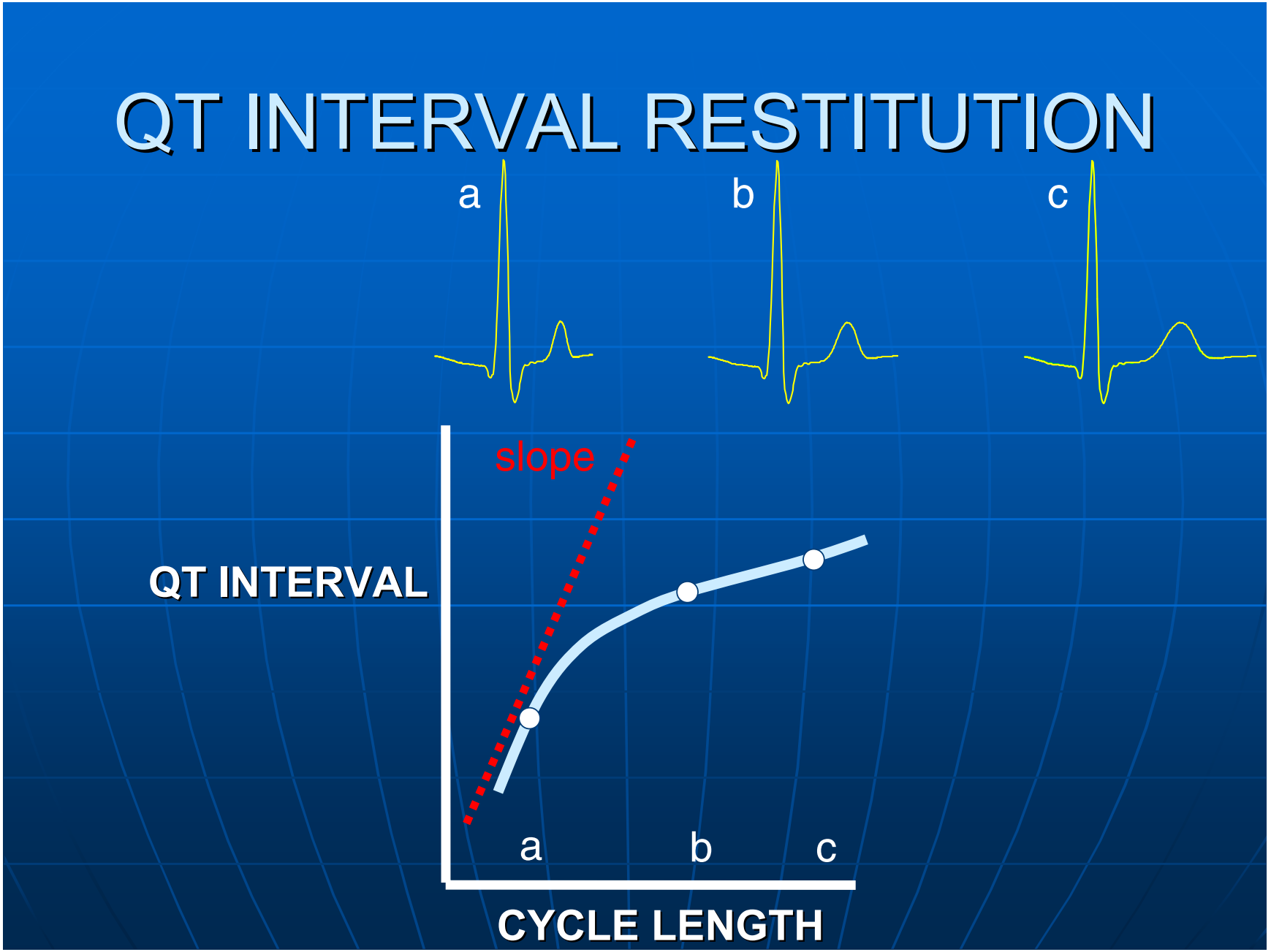


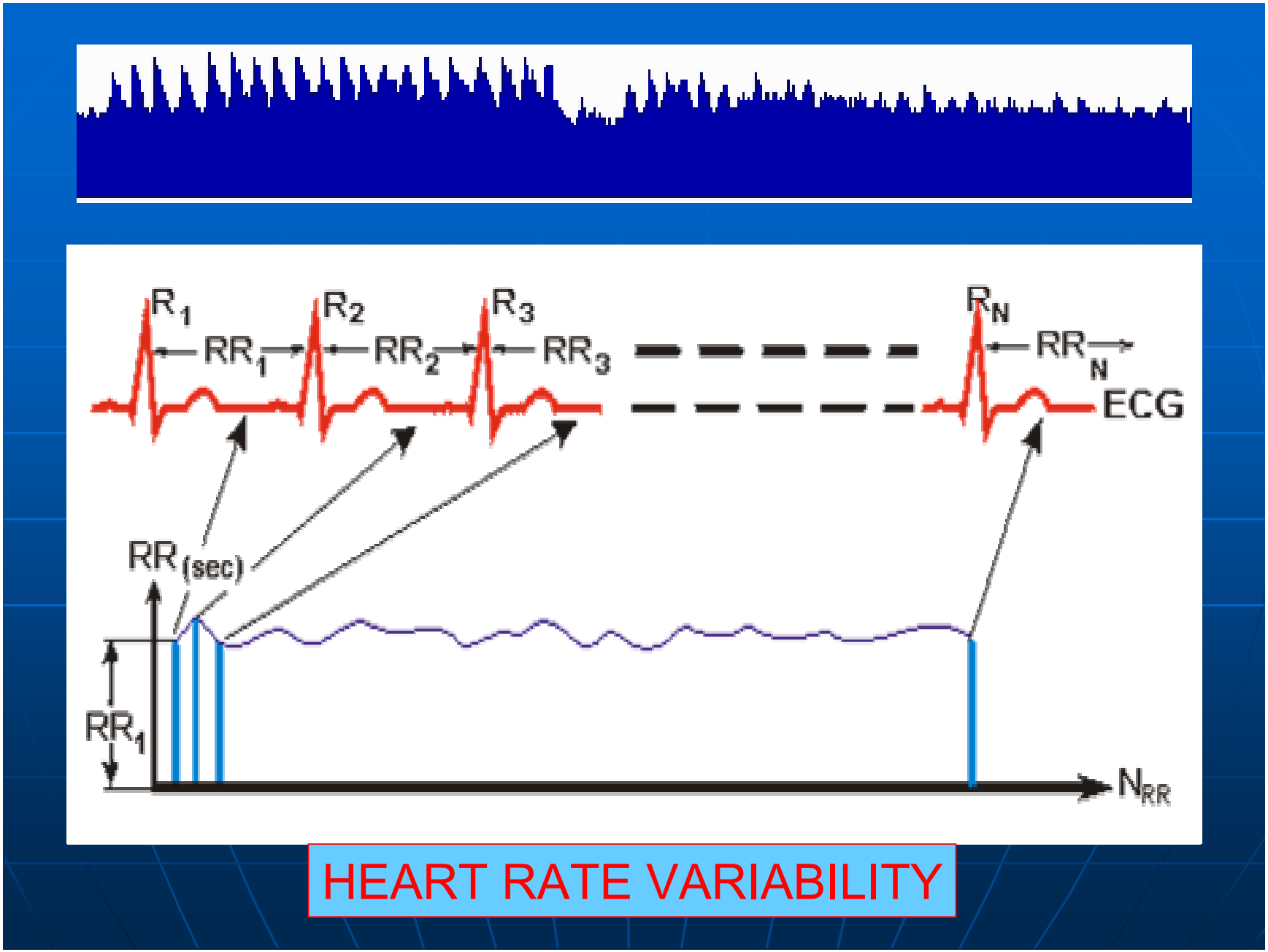
Rosenbaum et al. *N Engl J Med* 1994;330:235-241

Heart Rate Dependence of T Wave Alternans

Kaufman E, et al. *Am J Physiol*. 2000;279:H1248-H1255.

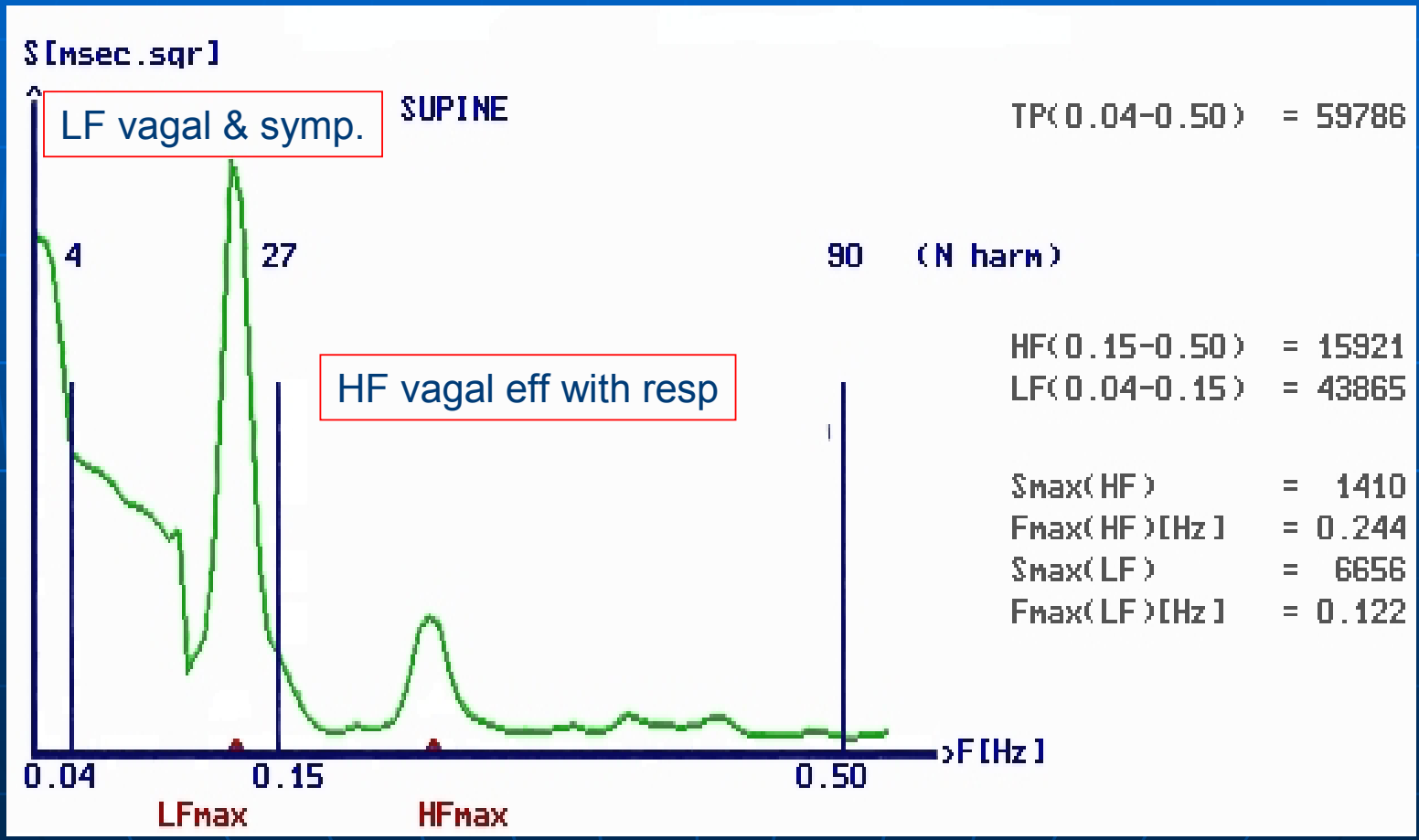



QT INTERVAL RESTITUTION
a
b
c
slope
QT INTERVAL
a
b
c
CYCLE LENGTH



HEART RATE VARIABILITY

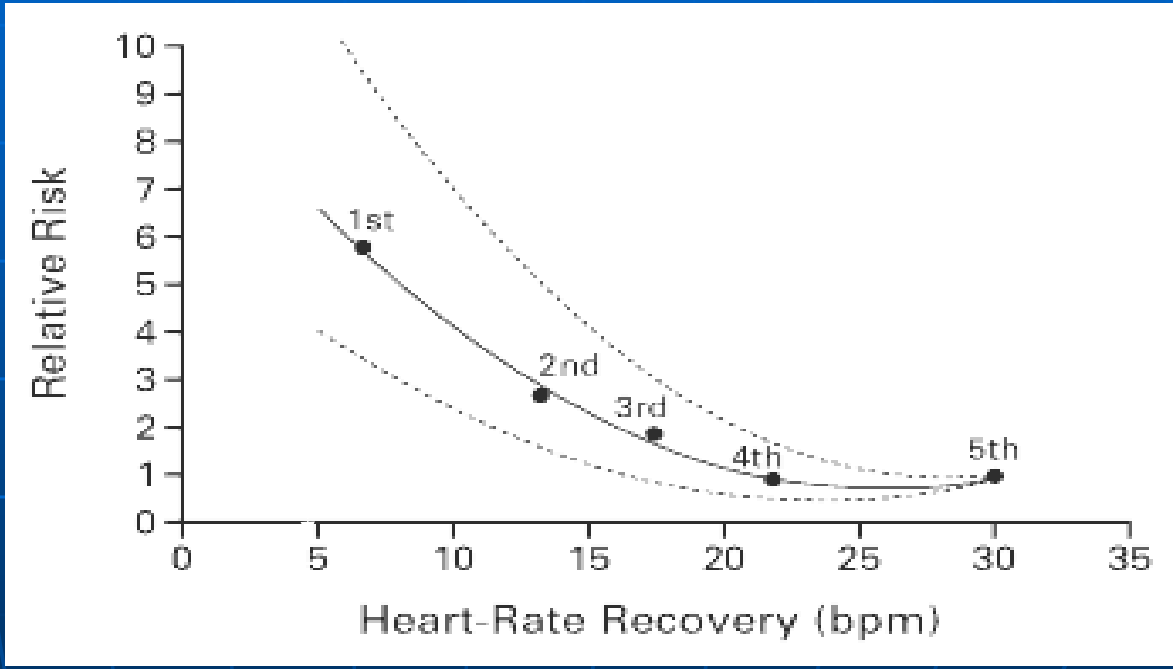
POWER SPECTRAL ANALYSIS OF HRV



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



Cole CR et al. NEJM 1999 Oct; 341: 1351-57.

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.