

# On-Orbit Prospective Echocardiography on International Space Station

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# Learning Objectives

1. The audience will understand concepts behind remotely guided echocardiographic imaging from remote locations such as the ISS.
2. The audience will understand the approach of Benjamini, Krieger and Yekutieli (2001) to allow a moderate “false discovery rate” and modify the standard P-value threshold from 0.05 to a lower value for declaring “significance”
3. The audience will understand this study found no consistent effects of long-duration space flight on echocardiographic variables of the given group of subjects



# Introduction

- A number of echocardiographic research projects and experiments have been flown on almost every space vehicle since 1970, but validation of standard methods and the determination of 'Space Normal' cardiac function has not been reported to date
- Advanced Diagnostics in Microgravity (ADUM) - remote guided echocardiographic technique provides a novel and effective approach to on-board assessment of cardiac physiology and structure using a just-in-time training algorithm and real-time remote guidance aboard the International Space Station (ISS)

# Introduction – Cont.

- The validation of remotely guided echocardiographic techniques provides the procedures and protocols to perform scientific and clinical echocardiography on the ISS and the Moon
- The objectives of this study were:
  1. To confirm the ability of non-physician astronaut/cosmonaut crewmembers to perform clinically relevant remotely guided echocardiography using the Human Research Facility on board the ISS
  2. To compare the preflight, postflight and in-flight echocardiographic parameters commonly used in clinical medicine

# ULTRASOUND

P N E U M O T H O R A X

# Cardiac Monitoring Occurrences

- Selection
- Annual physicals
- Parabolic flight
- Preflight
- In Flight
- Postflight





# ADUM

ADVANCED DIAGNOSTIC ULTRASOUND IN MICROGRAVITY

# OPE

- CD-ROM based "just-in-time" On Board Proficiency Enhancement (OPE) will reduce the amount of ground-based guidance needed to acquire advanced ultrasound images.

ARE YOU PREPARING TO SCAN:



PRINCIPLES OF REMOTE GUIDANCE  
SHIFT F1

DATA ACQUISITION  
SHIFT F8

CARDIAC

THORACIC

ABDOMINAL

BONE

EXERCISES  
SHIFT F4

BLOOPERS  
SHIFT F10

CONCLUSIONS  
SHIFT F11

PREVIOUS SECTION  
SHIFT ↑

NEXT SECTION  
SHIFT ↓

VOLUME: 25%

VIEW REMOTE GUIDANCE CARD

Pyc/AHFA

QUIT SWITCH USER

OPE 2.0



DETAIL

POSITION DESCRIPTION

PLACE THE PROBE IN THE L1 POSITION.

BACK SHIFT SPACE NEXT SPACE

QUIT

VOLUME: 25%

MAIN MENU

MANDATORY RECOMMENDED OPTIONAL

INTRODUCTION  
SHIFT F1

EXPERIMENT OVERVIEW  
SHIFT F2

BRAIN GYM  
SHIFT F3

HARDWARE SETUP  
SHIFT F5

ANATOMY  
SHIFT F6

PRINCIPLES OF ULTRASOUND  
SHIFT F4

PRINCIPLES OF REMOTE GUIDANCE  
SHIFT F1

DATA ACQUISITION  
SHIFT F8

EXERCISES  
SHIFT F4

BLOOPERS  
SHIFT F10

CONCLUSIONS  
SHIFT F11

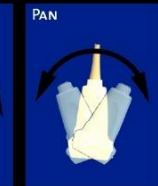
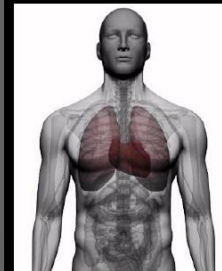
## EXPERIMENT OVERVIEW

PAGE 2 OF 3

THE GOALS OF OPE (ONBOARD PROFICIENCY ENHANCER) ARE TO:

- HIGHLIGHT THE CONCEPT OF REMOTELY GUIDED ULTRASOUND
- REINFORCE REMOTE GUIDANCE TERMINOLOGY AND SCANNING TECHNIQUES.
- REVIEW HARDWARE CONFIGURATION
- EMPHASIZE ESSENTIAL HUMAN ANATOMY
- PREPARE FOR SPECIFIC SCANNING PROTOCOLS
- CAPTURE INFORMATION ABOUT THE UTILITY OF OPE

### PROBE MANIPULATION



PREVIOUS SECTION  
SHIFT ↑

NEXT SECTION  
SHIFT ↓

VOLUME: 25%

VIEW REMOTE GUIDANCE CARD

Pyc/AHFA

QUIT SWITCH USER

OPE 2.0

BACK SHIFT SPACE NEXT SPACE

# Make it Fun!!!!

MANDATORY RECOMMENDED OPTIONAL

- INTRODUCTION (SHIFT F1)
- EXPERIMENT OVERVIEW (SHIFT F2)
- BRAIN GYM (SHIFT F3)
- HARDWARE SETUP (SHIFT F4)
- ANATOMY (SHIFT F5)**
- PRINCIPLES OF ULTRASOUND (SHIFT F6)
- PRINCIPLES OF REMOTE GUIDANCE (SHIFT F7)
- DATA ACQUISITION (SHIFT F8)
- EXERCISES (SHIFT F9)
  - FIND YOUR FOOT
  - TU NING
  - ART CRITIC
  - WHERE'S VAHLDAO?
  - ANATOMY LESSON**

- BLOOPERS (SHIFT F10)
- CONCLUSIONS (SHIFT F11)

PREVIOUS SECTION (SHIFT ↑) NEXT SECTION (SHIFT ↓)

VOLUME: 25%

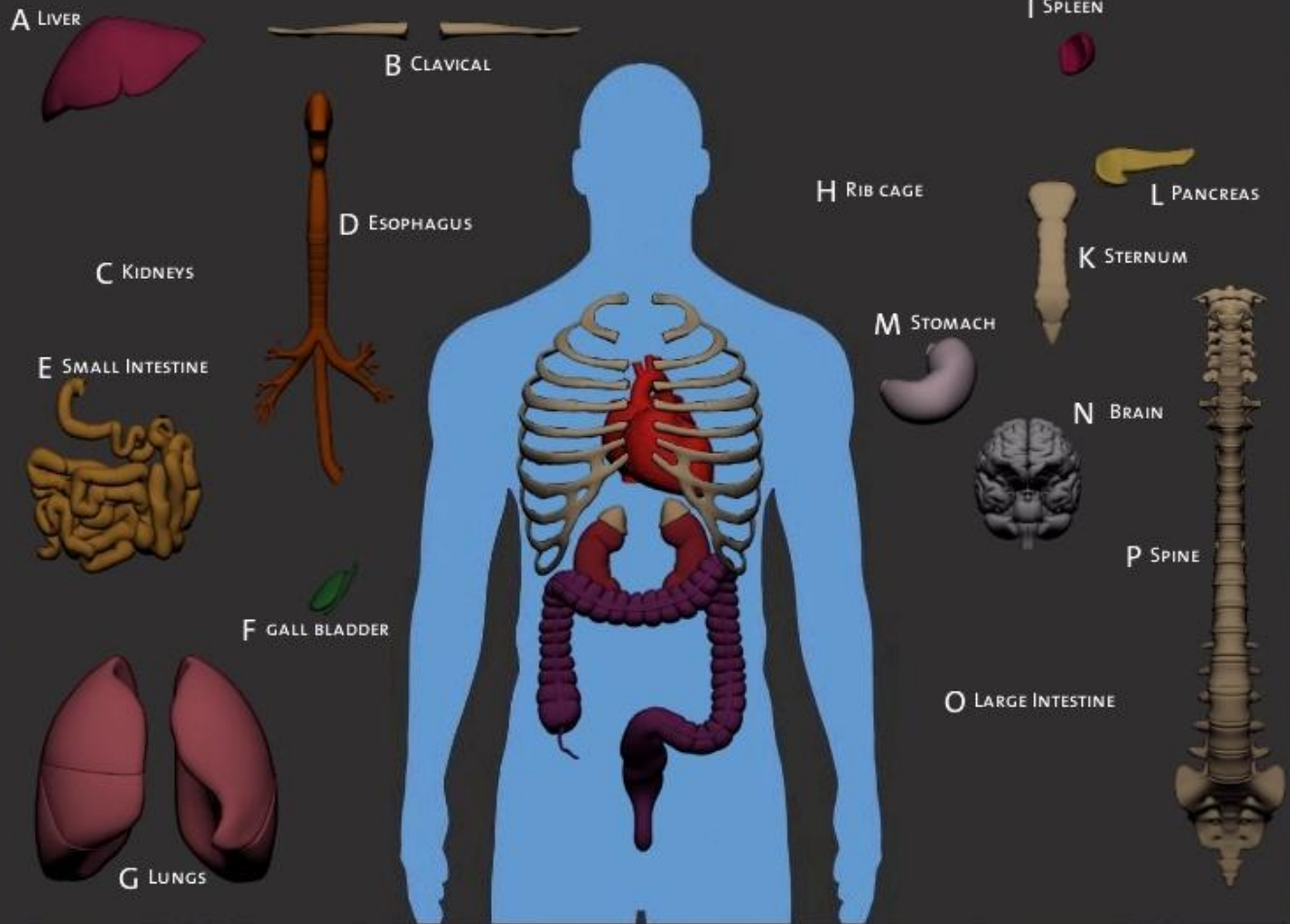
VIEW REMOTE GUIDANCE CARD (SHIFT V)

РУС/АНГ (SHIFT L)

QUIT (ESC) SWITCH USER (SHIFT ESC)

OPE 2.0

## ANATOMY LESSON



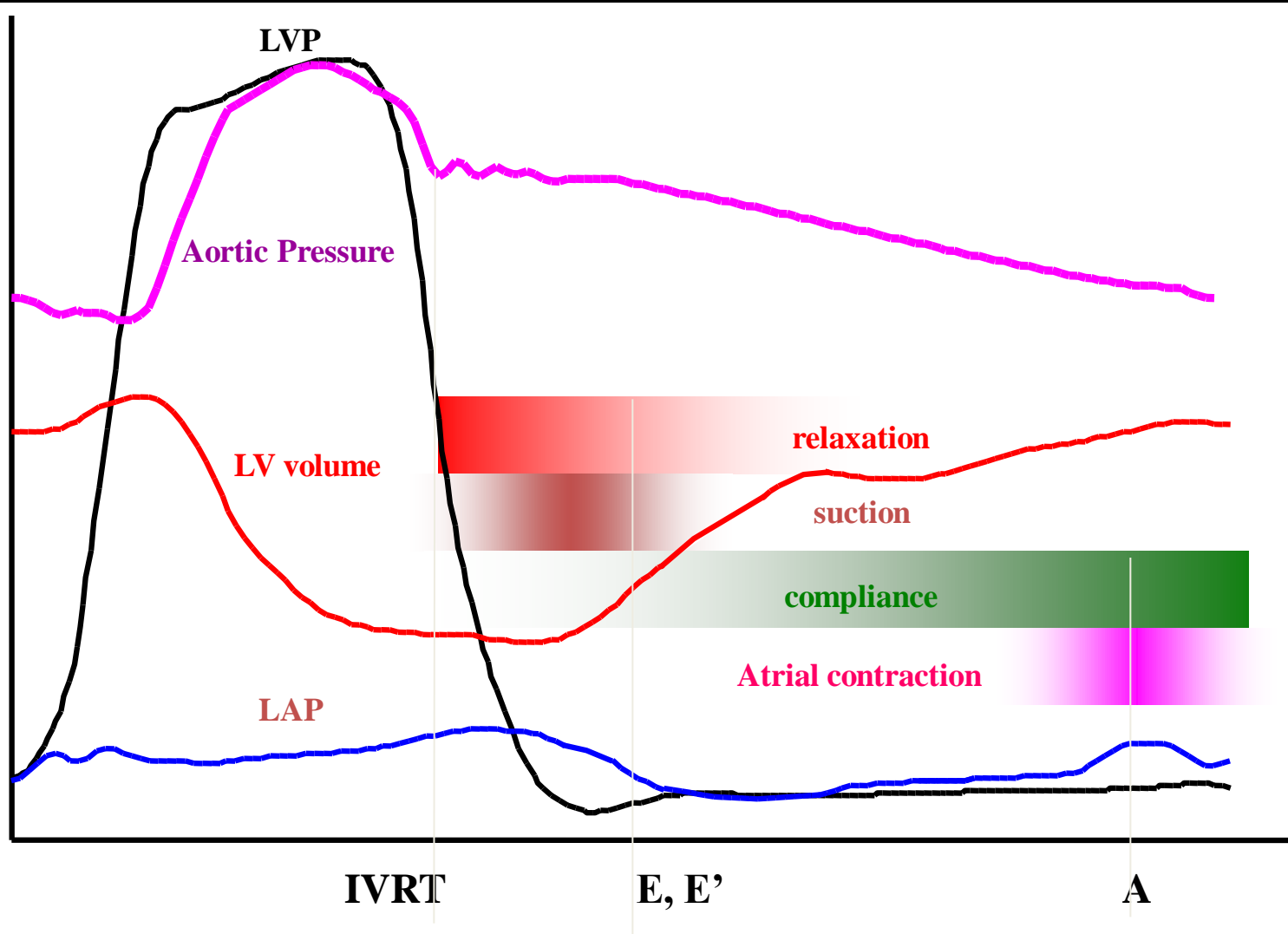
### Instructions

PRESS A THROUGH P OR USE THE MOUSE TO SELECT AN ORGAN.

THEN USE THE ARROW KEYS OR THE MOUSE TO POSITION THE ORGAN INSIDE THE BODY.



# Doppler Assessment of Myocardial Relaxation



Echocardiography parameters:

Prasad et al. Am J Cardiol 2007 Courtesy Ben Levine



# Maximal Cross-Sectional Changes

75 % Range!

## Longitudinal Changes

37.5 % Range

% Baseline LV Mass Index

140  
130  
120  
110  
100  
90  
80  
0

Spinal cord  
Injury

Bed rest

Base

Training

Elite  
Runners

(from deGroot et al, unpublished observations)

(from Milliken et al, Am J Cardiol 1998)



# Is cardiac function a significant concern and should it be monitored?

- Need on-orbit echo data with cardiovascular interventions to better understand the physiology and space normal clinical findings
- In the past, astronauts have not been able to “get the shot” for retrospective analysis
- Pre/Post flight data are high fidelity because experience echo technicians are collecting the data

Space



Earth



# Experiment Design

PREFLIGHT	IN FLIGHT	POSTFLIGHT
Baseline ultrasound scan and simulation training ~L-240 days (Incr. 8 - August 2003)	OPE (all increments) Operator only $\leq 7$ days before scan	Baseline ultrasound exam ~R+10 $\pm$ 7 days (Russia)
On-board Proficiency Enhancer (OPE) and Preflight ~L-180 and 3 days	Exam Scan (Cardiac, Thoracic, Abdominal, Bone ,Muscle)	
	Session Analyses ** Within 7 days post scans set	

\*\* "Restricted access" voice loop required

Notes:

Restricted Audio/Video Communication for real-time remote guidance sessions.



# Methods

- Each crewmember operator (n=6) had 2h preflight training. Baseline data were collected 55 to 167days preflight with HDI-5000 (ATL/Philips, Bothell, WA) ultrasound system
- Similar equipment was used in each 60-minute in-flight session (microgravity exposure - 114 days (34 – 190))
- Operators used an e-learning system (in this case, OPE) within 24h of these sessions. An expert in echocardiography provided assistance using ultrasound video downlink and 2-way voice
- Testing was repeated 5 to 16 days after landing

# Data Analysis

- Separate ANOVA was used on each echocardiographic variable (n=36)
- Within each ANOVA, three tests were made:
  - A. effect of mission phase (preflight, in flight, postflight)
  - B. effect of echo technician (two independently analyzed the data)
  - C. interaction between mission phase and technician.
- In the resulting 108 tests, some of the “significant” findings ( $P < 0.05$ ) were expected to be false
- A “false discovery rate” of 15% was assumed (Benjamini, Krieger and Yekutieli approach) , still retaining enough power to identify potentially important effects of mission phase, technician, or both
- A revised P-value threshold was calculated to be 0.0116

# Each analyst measured the following parameters

- LA Systolic Diameter
- LV Diastolic and Systolic Diameter Base Length and Posterior Wall Thickness
- LV Mass (Simpson and m-mode)
- LV diastolic length=a+d (cm)
- LV Outflow Tract Diameter and Time Velocity Integral
- RV Area Diastole and Systole
- RA Area Diastole and Systole
- % Change in RV and RA Area
- Mitral E and A-wave Velocity
- Atrioventricular Time Velocity Integral
- Fractional Shortening
- Ejection Fraction (by area and volume)
- Interventricular Septal Diastolic and Systolic Thickness
- Isovolumic Relaxation and Contraction Time
- Endocardial and Epicardial Area
- A Wave Duration
- Heart Rate
- Diastolic and Systolic 4-Chamber Volume by 2D
- Cardiac Output

# ADUM Cardiac Exam



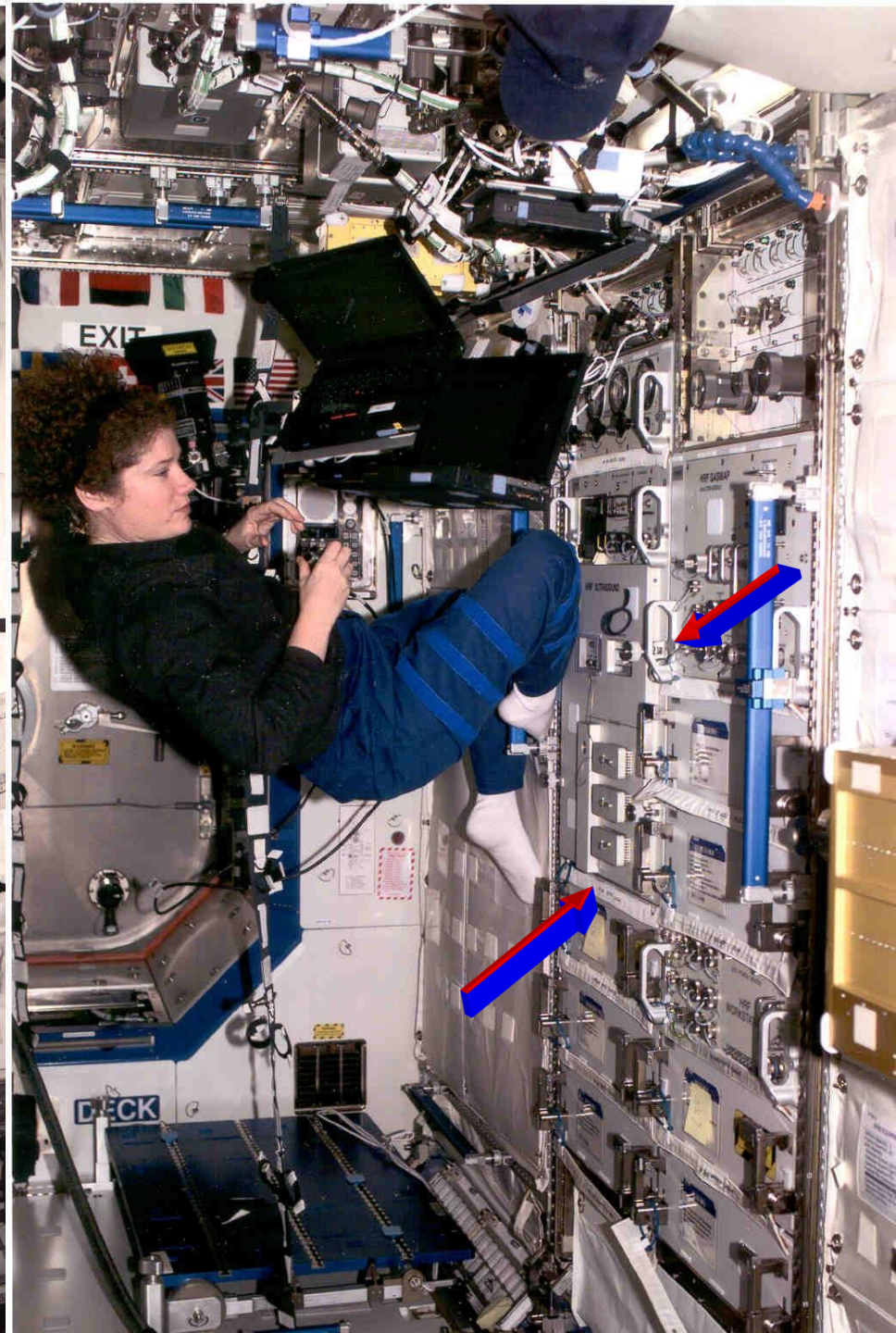
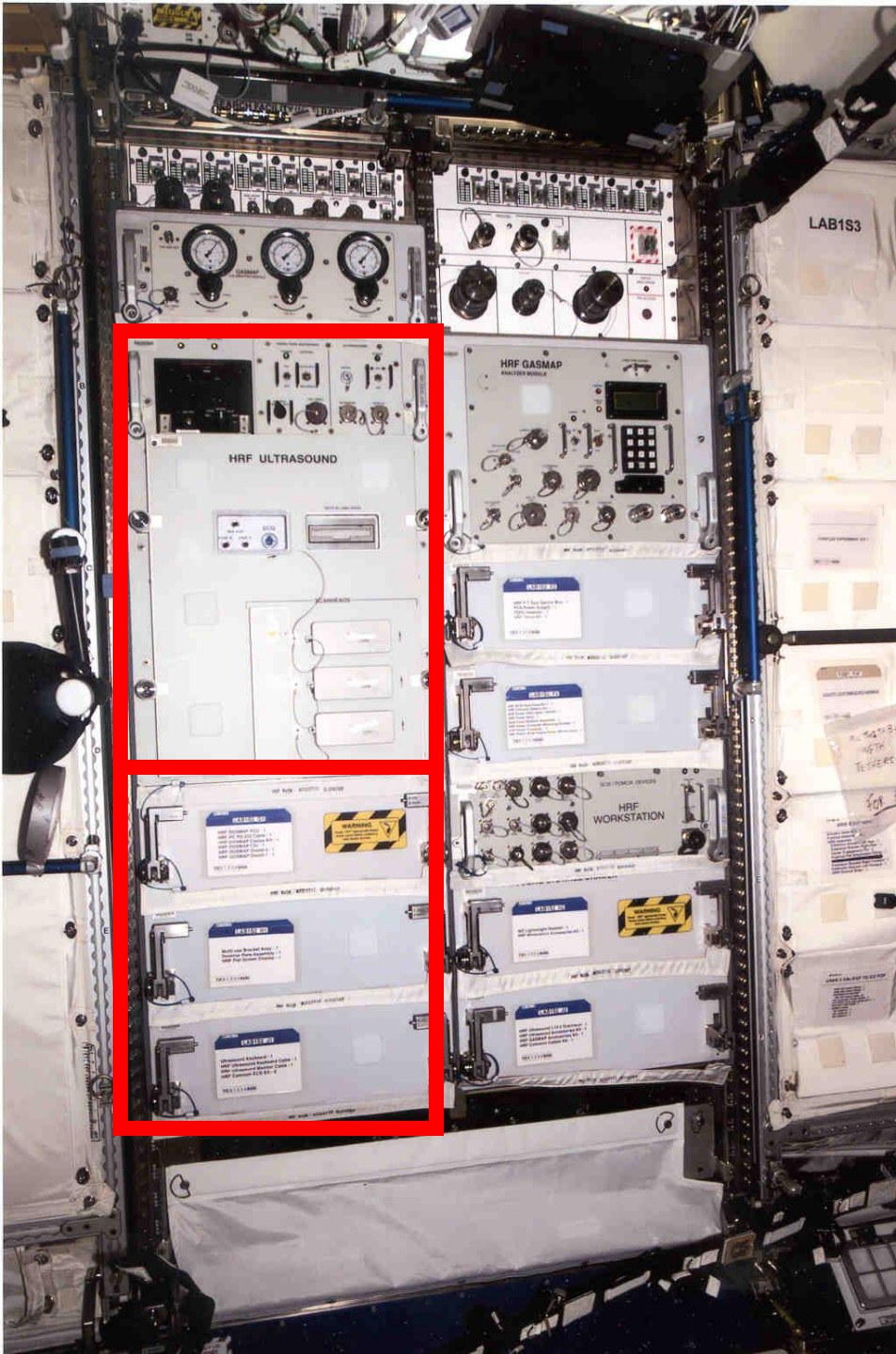
# The Method of Benjamini, Krieger and Yekutieli

- When running 108 tests (36 ANOVAS, 3 tests per each), some of the “significant” findings (corresponding to  $P < 0.05$ ) might be spurious
- To compensate for this, we used the approach of Benjamini, Krieger and Yekutieli to allow a moderate “false discovery rate” of 15%, but still retain enough power to identify potentially important mission phase, analyst, or interaction effects
- Applying this procedure for our data resulted in a revised P-value threshold of 0.0116
- If this experiment and analysis procedure were to be repeated, one would expect on average that perhaps one or two of the rejections of the NULL hypothesis were false



# The Method of Benjamini, Krieger and Yekutieli – Cont.

- *“Significance” is only in a statistical sense and may not represent clinically meaningful differences*
- 9 tests were “significant” (i.e., a rejection of the null hypothesis) using the method of Benjamini, Krieger and Yekutieli with an FDR of 0.15
  - 6 rejections for significant technician effects (LV systolic diameter base length, LV posterior wall systolic thickness, A-wave duration, Inter-ventricular septum diastolic and systolic thickness and LV mass)
  - 3 rejections of the null hypothesis were attributable to space flight (Atrio-ventricular velocity time integral, Mitral E wave, Heart rate)





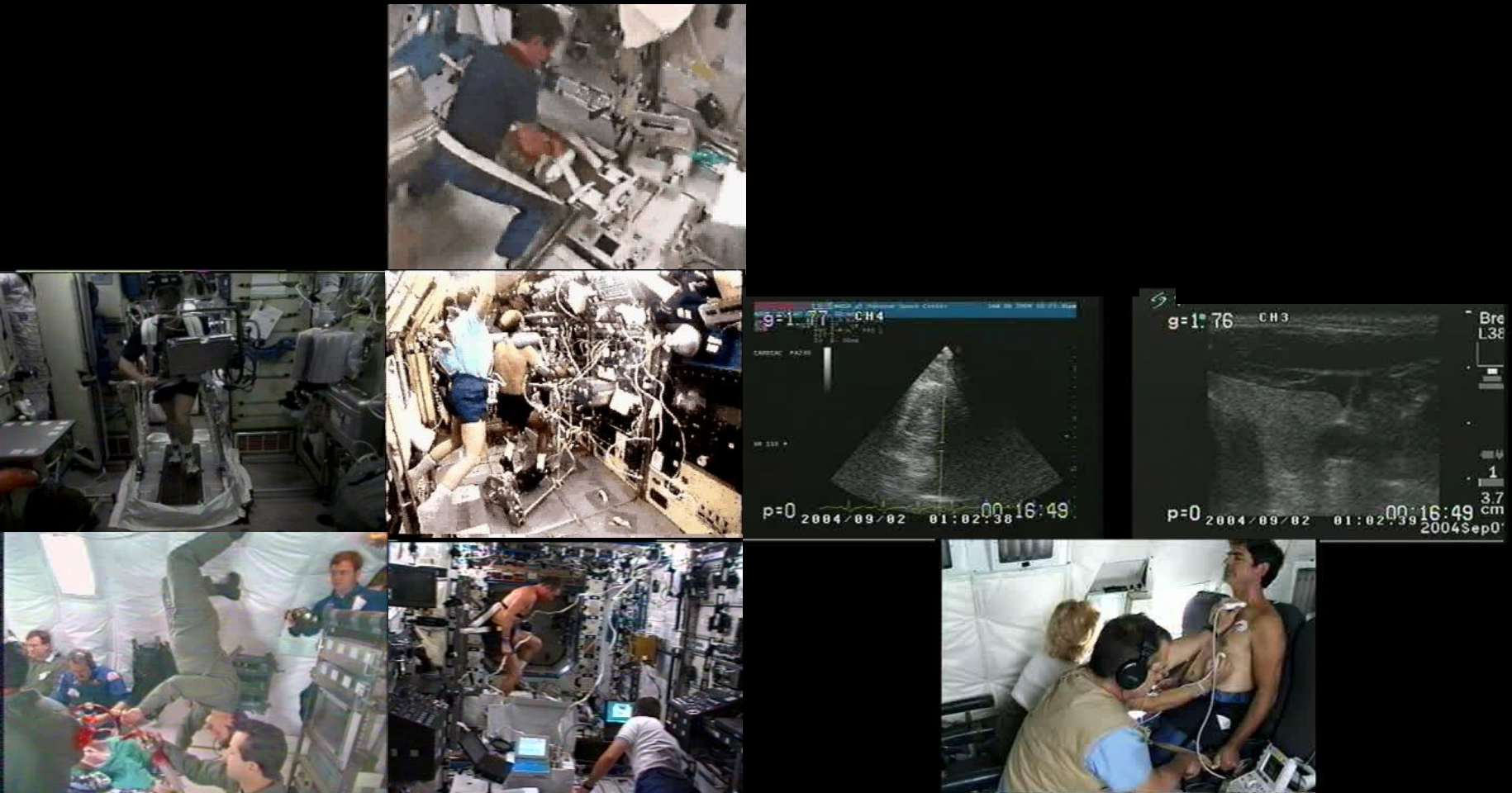
# Results

- 9 rejections of the null hypothesis (mission phase or technician or both had no effect) were found that could be considered for possible follow up
- Of these
  - 6 rejections were for significant technician effects
  - 3 were attributable to space flight
    1. Atrioventricular velocity time integral
    2. Mitral E wave
    3. Heart Rate
- None were due to the interaction between technician and space flight
- Thus, we find no significant effects of long-duration space flight on clinical echocardiographic variables for the given group of subjects

# Conclusion

- Current ISS mission medical prevention strategies seem to prevent grossly obvious cardiac abnormalities
- Remotely guided echocardiography can be used for payload science and clinical studies where temporal communication delays are less than 6 seconds (i.e., Moon and the Lagrange Point)
- If space-related changes in cardiovascular function measured by echocardiography exist, a larger cohort and more controlled conditions need to be implemented ( Integrate Cardiovascular Study – Levine and Bungo – currently manifested )

# Questions?



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