Space Exploration: Challenges in Medicine, Research, and Ethics

Jeffrey R. Davis, M.D.
Director, Space Life Sciences
NASA Johnson Space Center
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Effects of Microgravity on Human Physiology

- Neurovestibular
- Cardiovascular
- Radiation
- Behavior & performance
- Bone
- Muscle

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Space Studies and Results
Radiation

• Causes
  – Galactic cosmic rays
  – Protons and electrons trapped in Earth’s magnetic field
  – Solar particle events

• Consequences
  – Cataracts
  – Cancer
  – Central nervous system damage
  – Acute radiation sickness
Radiation

Countermeasures

- Shielding
- Pharmacotherapeutics
Bone

• Causes of bone loss
  – Interplay among biomechanical factors, hormonal and metabolic balance
  – Skeletal unloading

• Consequences
  – Increases clinical risk of
    • Stress/traumatic fractures
    • Impaired fracture healing
    • Soft tissue injury
    • Renal stone formation
Bone

- Countermeasures
  - Exercise
  - Nutrition
  - Artificial gravity
  - Pharmaceuticals
    - Midodrine for postflight orthostatic hypotension
    - Alendronate for bone loss
Behavior and Performance

• Causes of changes
  – Sleep loss, circadian desynchronization
  – Fatigue and work overload
  – Planned and unplanned events
  – Spacecraft environment

• Consequences
  – Stress-induced anxiety
  – Crew or crew/ground control conflict
  – Psychosomatic complaints
Behavior & Performance

Countermeasures

- Schedule changes to minimize crew fatigue and reestablish circadian rhythms
- Family contacts
- Private medical conferences
- LED blue light treatment

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Muscle

- **Causes of loss**
  - Muscle protein synthesis
  - Lack of muscle loading

- **Consequences**
  - Loss of strength, power, and endurance
  - Increased excretion of muscle breakdown metabolites (nitrogen, potassium, creatine, amino acids)
Muscle

Countermeasures

- Medications
- Aerobic and resistive exercise regimens
Cardiovascular

• Causes
  – Fluid pools in upper body
  – Blood volume and heart volume decrease

• Consequences
  – Aerobic capacity decreased
  – Heart rate decreased
  – Cardiac output increased
Cardiovascular

Countermeasures:
- Exercise
- Pharmacology
- Treatment
  - CPR
  - Defibrillator

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Neurovestibular

• Causes
  – Altered sensory stimulus
  – Rearrangement of signals from eyes, muscle, vestibular receptors

• Consequences
  – Disorientation
  – “Motion” sickness
  – Perceptual illusions
  – Disturbances of
    • Eye-hand coordination
    • Balance control
    • Gait
Neurovestibular

• Countermeasures
  – Training
  – Pharmacological
  – Spatial re-orientation
Food and Nutrition

• Causes
  – Altered senses
  – Decreased appetite
  – Stress

• Consequences
  – Decreased fluid intake
  – Decreased energy intake
  – Preference for carbohydrates versus fat
  – Body composition changes
  – Fluid and electrolyte homeostasis
Food and Nutrition

Countermeasures

- Satisfy metabolic requirements
  - Water balance
  - Ample pantry for crew preferences
- Additional food
- Increased shelf-life
Immunology and Hematology

• Causes
  – Loss of plasma and red blood cells
  – Stress
  – Altered environmental, radiation, and chemical exposures

• Consequences
  – Decrease in red cell mass
  – Increase in white blood cell counts
  – Changes in the ability of lymphocytes to react to foreign materials
  – Number of lymphocytes decreased and neutrophils increased
Immunology and Hematology

Countermeasures

- Shielding (structural, chemical) for radiation
- Stress reduction
- Nutritional, pharmacologic, and immunologic prevention and treatment
- Microbiocidal prevention of opportunistic infection
Environment

- Causes
  - Acoustics
  - Microbiology
  - Radiation
  - Toxicology
  - Water quality
Environment

Countermeasures

- Monitoring
- Recycling water
- Waste management
- Air scrubbers
- Thermal control systems
- Radiation shielding
The Vision for Space Exploration
Transportation System to Low Earth Orbit

4-6 crew to lunar surface for extended-duration stay

2015 – 2020

Human exploration to Mars vicinity

2008 – 2014

Human exploration of Mars surface

2020 – TBD

Long duration human lunar exploration

2025+

2030+

Exploration
Building Block Approach

- Humans on the Moon
- Complete ISS
- Humans to Mars
Exploration Issues

- Communication delays (up to 40 minutes to Mars) and/or long periods without communication
- Limited or no ability to return to Earth for contingencies
- Autonomous clinical care
- Psychosocial, behavior and performance issues
- Improved therapeutics
- Increased diagnostic capabilities
- Integrated micro-g and low-g diagnostic/treatment protocols
- Medical consumables
Life Sciences’ Contributions

Environments

Habitability

Health Care
Health Care

- Medical requirements and standards
- Evidence-based medical care
- On-orbit clinical capabilities
- Medical selection and retention
- Crew certification
- Countermeasures
  - Physiological changes
  - Behavioral sciences
Habitability

- Human physical parameters
- Performance capabilities and limitations
- Crew station integration
- Crew interface analysis
- Habitat design
- Human-machine interfaces
- Space human factors
- Food systems
Environments

• External
  – Temperature extremes
  – Vacuum
  – Increased radiation levels (solar, cosmic)

• Internal (spacecraft)
  – Atmospheric composition and purity
  – Air, food, water, and noise
  – Spacecraft configuration
  – Microbiological concentrations & alterations
Questions?