Space Exploration: Challenges in Medicine, Research, and Ethics

Jeffrey R. Davis, M.D.
Director, Space Life Sciences
NASA Johnson Space Center
27 April 2007
Effects of Microgravity on Human Physiology

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

Jeffrey R. Davis, MD
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

Jeffrey R. Davis, MD
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
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
### Countermeasures

- **Radiation**
  - Shielding (structural, chemical) for radiation
- **Stress Reduction**
- **Nutritional, Pharmacologic, and Immunologic Prevention and Treatment**
- **Microbiocidal Prevention of Opportunistic Infection**

---

*Jeffrey R. Davis, MD*
Environment

• Causes
  – Acoustics
  – Microbiology
  – Radiation
  – Toxicology
  – Water quality
Environment

Countermeasures
- Monitoring
- Recycling water
- Waste management
- Air scrubbers
- Thermal control systems
- Radiation shielding

Jeffrey R. Davis, MD
The Vision for Space Exploration
Transportation System to Low Earth Orbit

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

Human exploration to Mars vicinity

Human exploration of Mars surface

Long duration human lunar exploration

2008 – 2014

2015 – 2020

2020 – TBD

2025+

2030+

Jeffrey R. Davis, MD
Building Block Approach

- ISS Complete
- Mars
- Humans to Mars
- The Moon
- Humans on the Moon
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

Health Care

Environments

Habitability
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