Space Exploration: Challenges in Medicine, Research, and Ethics

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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
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

Sunset over North America 2-1-03
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
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

National Aeronautics and Space Administration

The Vision for Space Exploration
February 2004

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Transportation System to Low Earth Orbit

Human exploration of Mars surface

Human exploration to Mars vicinity

Long duration human lunar exploration

2015 – 2020

2020 – TBD

2025+

2030+

2008 – 2014

4-6 crew to lunar surface for extended-duration stay
Building Block Approach

Humans on the Moon

Humans to Mars

Complete ISS
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

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Life Sciences’ Contributions

Health Care

Habitability

Environments
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