Medical Risks for Long Duration Spaceflight

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The Challenge

- Identify the risks, promote mission success by maintaining crewmember health and performance, and mitigate long term health effects of spaceflight
The Work Environment

- Microgravity, partial gravity
- Acceleration changes
  - Launch, entry, landing
- Vacuum and reduced pressure
- Radiation
- Isolation and confinement
- Noise
- Toxic exposures
- Microbiology
- Dust
- Remote from definitive medical care
Responses to Spaceflight

- As far back as Apollo program numerous physiological changes were noted
- Physiological changes are an adaptation to loss of the gravity vector
- Different systems adapt at different rates
- Psychological responses should not be underestimated
Managing Risk

• Standards
  – Selection, retention
  – Continually reviewed

• Aerospace Medicine Board
  – Applies standards and provides waiver if indicated
  – International partners

• Engineering solutions

• Establish exposure limits
  – Radiation, hazardous materials

• Periodic examinations

• Countermeasures

• Clinical practice guidelines
Intracranial Hypertension

- Several cases among long duration crewmembers
  - Each with different degrees of symptoms
  - Elevated measures of Intracranial Pressure (ICP) post flight
  - Evaluation of shuttle fliers showed changes in the optic nerve diameter, even in 14 day missions.

- Hyperopic Shifts
  - Up to +1.75 diopters

- Globe Flattening

- Choroidal Folds - parallel grooves in the posterior pole

- Optic Disc Edema (swelling)

- Altered Blood flow
  - “cotton wool” spots

- Increased Optic Nerve Sheath Diameter
Neurovestibular Adaptation

- Neurovestibular function perturbed after transition to different g environment
- Most immediate and obvious sign of physiological challenge going up or down
- Impairment on return appears to be greater with longer duration flights
- The severity of performance decrements are variable between crewmembers
- Medications can mitigate immediate sensations of nausea
- No reliable predictors
- Postflight goal is return to baseline ASAP
Cardiovascular Changes

• Incidence orthostatic intolerance (OI) is ~20% after STS missions
  – Higher incidence of OI in women & first time flyers
  – Influenced by plasma volume loss secondary to cephalad shift of blood during μ-g
  – Exacerbated in some astronauts by blunted sympathetic response to standing
• Effective operational countermeasures to OI in STS include:
  – Fluid loading protocol before re-entry
  – Use of liquid cooling garment to prevent elevated body temperatures in ACES
  – Inflation of anti-gravity suit (AGS) during re-entry & immediate post-landing
• No increased incidence of arrhythmias & no significant loss of cardiac mass but potential decrease in diastolic function
• Decreased aerobic capacity (VO$_2$max) & altered sub-maximal exercise responses which can be ameliorated by exercise countermeasures
  – Inflation of AGS may further impair emergency egress capacity
• Concern is ability to perform routine and emergency tasks during mission and after return
• Strongly desire to minimize time required for reconditioning after return to Earth
Musculoskeletal system

• Bone remodeling takes place constantly in the 1g environment, with deposition and resorption essentially balanced or very slightly weighted toward resorption
  – Experience osteopenia, osteoporosis as we age
• In microgravity, metabolism shifts toward bone resorption primarily due to loss of weight-bearing loads
  – Results in decreased bone mineral density in spine, pelvis, leg bones
  – Increased urine calcium loads can lead to kidney stones
• Postflight, despite new bone deposition changes in architecture of bone may affect fracture risk
Musculoskeletal system

- Muscle atrophy and loss of strength occur in postural and lower extremity muscles.
  - Also due primarily to loss of typical 1-g loading.

- Exercise countermeasures can reduce loss of bone density and muscle mass.
- Goal is to minimize required postflight reconditioning and restore function and risk to appropriate levels for age and gender.
Musculoskeletal system

• Can they perform the required routine and emergency tasks when they arrive at planet or return to earth?

• Can they recover and lead normal lives?
Exercise Countermeasures

- Treadmill
- ARED
- CEVIS
- Veloergometer
Space Radiation

- As missions move beyond low earth orbit, Solar Proton Events (SPEs) and galactic cosmic radiation become much more significant factors in risk assessment.
- NASA astronauts are considered radiation workers and the US Code of Federal Regulations requires that exposure guidelines be in place. Career limits of exposure are designed to protect astronauts to no more than 3% increase in lifetime cancer mortality. To ensure that this risk is not exceeded, exposure is managed to a 1% increased risk level.
- Uncertainties in the cellular and molecular effects of this radiation limit ability to assess risks & countermeasures.
Space Radiation

• The threat of SPEs and GCR require new operational and shielding approaches, new biological data on risks, new monitoring hardware
Behavioral Health

• Crew Isolated and confined
  – Experience many stressors
  – Usual coping mechanisms unavailable

• Can result in cognitive and psychiatric problems

• Serious life events can be very challenging
Behavioral Health

• Deploy many countermeasures
  - Pre-selection screening
  - Media
  - IP phone
  - email
  - Family conferences
  - Psychological conferences

• Looking for ways to monitor sleep
  - Actigraphy, ECG

• Simulated Mars missions
Inflight Medical Care

• Support constrained by upmass, stowage, power, resupply, crew skill set
• Delivery to definitive care not immediate
• As we move beyond LEO, crew must function autonomously
  – Communication delays
  – No possibility of return
• Develop models that predict needs
• Preventive medicine and screening
• Enhance capability and training
Recommendations for Future Programs

Cohesive research environment
- Provide a multi-disciplinary physiological approach to research
- Knowledge sharing between clinicians & scientists
- Foster data sharing & integrated testing approaches among scientists
- Use of ground analog platforms as precursors to space investigations
- Use of LEO platform as analog for planetary missions

Integration of operations & science
- Use of Preventive Medicine and selection standards to decrease risk
- Integration of medical & science activities to reduce impact on the crew
- Provide for Occupational Surveillance of work related illness or injury for long-term evaluation and effects from this unique work environment.