Space Medicine

Gilles Clément

International Space University
Strasbourg, France

Nurse Christine Chapel and Dr. Leonard ‘Bones’ McCoy in the original Star Trek TV series. Photo Paramount Pictures
Lecture Outline

• **Space Medicine**: What it is

• What are the **health hazards** of space flight

• **Chain of medical care**

• Medical **selection** of astronauts and **prevention** of health hazards

• In-flight **countermeasures**

• **Treatment** of medical events in space. The onsite medical facility.

• **Emergency** and **rescue**
Space Medicine

• **What it is**
  – It involves **proactive** and **reactive** care of humans to optimize physical, physiological, and mental well-being, within the unique constraints of an extreme environment.

• **What it isn’t**
  – *Space Medicine* is different from *Space Physiology*.
  – Many aspects of adaptation to weightlessness are **peculiarities**, not necessarily **pathology**.
  – Even if not pathological, changes may alter the way a disease presents or may increase **risks** for a given medical problem.
Space Medical Operations

- Medical Requirements Documents
- Astronaut medical selection and certification
- Biomedical training on medical systems, procedures, and protocols
- Pre-, in-, and post-flight health evaluation and monitoring
- Delivery of prevention, diagnostic, and therapeutic care
- Environmental health and monitoring
- Crew countermeasure implementation
- Emergency medical services
- Crewmember rehabilitation and fitness evaluations
History of Space Medicine
1. healthy crew – healthy vehicle
2. sick crew – healthy vehicle
3. healthy crew – sick vehicle (Mir)
4. sick crew – sick vehicle (Apollo-13)
Medical Events in Flight

**Medical Evacuation from Space:**
- Salyut-5, 1976 – Headaches following probable combustion event; 49 days into 54-day mission
- Salyut-7, 1985 – Urinary tract infection (prostatitis) → sepsis; 56 days into 216-day mission
- Mir, 1987 – Heart rate irregularity (cardiac arrhythmia); 6 months into 11-month mission

**Medical Events in Flight with Mission Impact**
- Apollo – EVA rescheduled due to motion sickness
- Apollo – Decompression sickness in CM pilot
- Apollo – Urinary tract infection during mission
- Apollo – Cardiac irregularity during lunar EVA
- Salyut – Kidney stone (near evacuation)
- Shuttle – 4 cases of urinary retention resulting in bladder catheterization
- ISS – Crewmember pulled from EVA due to cardiac abnormalities
Near Misses

- Cardiac events just prior to, or within 2 years after flight
- Adverse reactions to IV injections
- Brain tumor diagnosis and death 8 months after mission
- Physical fatigue: assistance required to ingress vehicle during EVA
- Inhalation injury post-fire
- 2nd degree burns
- Anxiety reaction on boarding a space station
- Rapid cabin depression secondary to breach of hull
- Chemical pneumonitis due to toxic exposure
Medical Problems Most Encountered

Most frequent

1. Loss of appetite
2. Space sickness
3. Fatigue
4. Insomnia
5. Dehydration
6. Skin inflammation
7. Back pain
8. Respiratory infection
9. Eye irritation
10. Bruises under fingernails from EVA suit gloves

11. Urinary tract infection
12. Abnormal heart beats
13. Headache
14. Muscle strain
15. Diarrhea
16. Constipation
17. Ear problems from pressure difference
18. Bends (limb pain caused by decompression)
19. Lung inflammation from chemicals inhalation

Least frequent
Common Medical Events in LEO

- **Space Motion Sickness** — count on 50-70% incidence
- **Foreign bodies in the eye** — particles do not “settle out”
- **Decompression-related disorders** — especially with active EVA schedule
- **Toxic inhalation** — risk from chemicals/reagents involved in investigations, pyrolysis products from fire, propellants
- **Kidney stones** — risk due to mobilization of calcium from skeleton, and possibly other factors
- **Radiation** — identified as the major career-limiting exposure for astronauts
Less Likely Medical Events

- **Cardio-vascular events** — Minimized by rigorous screening process during selection, flight certification

- **Major fractures** — forces which lead to such events terrestrially, such as vehicle accidents and falls, not largely present

- **Infectious disease** — after a certain disease free “incubation period” no new pathogens introduced into a small group (there are also immune system changes with unclear effects on overall risk)
Medical Events on Moon / Mars

- **Foreign bodies in the eye** — lunar dust will be a problem
- **Decompression-related disorders** — especially with active extravehicular activity schedule
- **Toxic inhalation** — from chemicals/reagents involved in investigations, industrial processes, pyrolysis products
- **Kidney stones** — risk due to mobilization of calcium from skeleton
- **Dental** — has been a problem on long-duration Mir and ISS missions
- **Trauma** — can expect injury-causing loads, wounds, lacerations, burns
- **Radiation** — Moon and Mars surface will be more severe than LEO
• “Common things occur commonly” – Medical events during space flight represent a large portion of events prompting visits to medical care facilities on Earth

• Mission-specific operational hazards – e.g. temperature; atmosphere; toxic substances, etc.

• Injury / illness is occurring in a body which is adapting to microgravity

• Manpower is in short supply

• In-flight, the crew is on its own with limited support from Earth
• Medical evacuations have occurred on orbit, therefore are highly likely during the operational lifetime of ISS or an exploration mission

• Risk of a significant illness or injury requiring equivalent of emergency room visit or hospital admission = 6-7% per person/year

• Risk of a significant illness or injury which would require advanced life support = 1-2% per person/year

• Based on:
  – US & Russian space flight data
  – USN Submarine crew data
  – Polar research station data
  – Astronaut and Military aviator data
Levels of Care for a Space Mission

- **Self-Care / Buddy Care**
  - Basic First Aid

- **Ambulatory Care**
  - Care for routine, minor medical problems

- **Basic Life Support**
  - Temporary emergency care

- **Advanced Life Support**
  - Oxygen, IV therapy, monitoring, defibrillation, medical procedures

- **Definitive Care**
  - In-depth diagnosis, complete treatment (including surgical intervention if indicated)

- **Chronic Care**
  - Long-term care during recovery and rehabilitation

- **Evacuation**
  - Transport to definitive or specialized care center
The Chain of Medical Care

- **Selection and Prevention** are the primary means of ensuring crew health and performance.

- **Countermeasures** are used when Selection and Prevention are unable to mitigate the deleterious effects of spaceflight.

- **Treatment** is used when Selection, Prevention, and Countermeasures are unable to prevent or mitigate illness or injury.

- **Stabilizing** and **Transporting** a patient from ISS to a DCMF (Definitive Care Medical Facility) are used when onboard Treatment is unable to mitigate illness or injury.

- **Re-habilitation** is used after landing for return-to-flight status.
The chain of medical care is only as strong as its weakest link
The Chain of Medical Care – Mars

- Physician astronaut
- Independent of Mission Control
- Able to make real-time decisions
- Able to deliver ambulatory and advanced life support care
• **Selection**
  – Identify and select-out *existing* pathology is not difficult
  – Select-out significant *medical risk factors* is more difficult
    • Most tests have a *poor ability* for detecting the presence of disease in very healthy individuals
    • No tests are designed to select-out the occurrence of pathology over the next three years

• **Prevention**
  – Emphasis is on *long-term health* maintenance to maximize career potential (investment in training)
  – *Health* is different from *Fitness*
Prevention

• **Pre-Flight**
  – Selection and mission medical standards
  – Medical readiness program
    • Fitness
    • Optimization of health
    • Crew rest

• **In-Flight**
  – Emphasis on safety
    • Vehicular components
    • Mission planning, esp. EVA
    • Flight rules
  – Reduce fatigue
  – Maintenance of Performance

• **Post-Flight**
  – Re-entry
  – Recovery
On-Board Medical Facility

• Health Maintenance System
  – Body Restraint System
  – Cardiac Defibrillator
  – Advanced Life Support Packs
  – Ventilator
  – Human Research Facility
    • Gas Analyzer System
    • Heart and vascular ultrasound
    • Abdominal ultrasound, deep organ
    • Gynecological ultrasound
    • Muscle and tendon ultrasound
    • Transcranial ultrasound

• Environmental Health System

• Countermeasures System
  – Treadmill
  – Cycle ergometer
  – Resistive exercise
• **Countermeasure**
  - A procedure, device, or process used to prevent or minimize adverse health and medical events resulting from exposure to short- or long-duration space flight, when selection and training methods have failed

• **Countermeasure Prescription**
  - Direction for a countermeasure including the modality (e.g., hardware device, drug, procedure), duration, intensity, and frequency, as well as the physiological monitoring equipment and parameters necessary to gauge its effectiveness
• Weight / volume – as small and compact as possible
• Simple and intuitive to use – training and competency will be limited
• Power/data needs – add immensely to complexity; non-powered if possible
• Long shelf-life, "bullet proof" technology desired
• Supports identified standard of care – meets clinical management analysis, eg. provides useful information
• Modular – easy to replace and upgrade components
• Think 0G or partial G as needed
• **Cardiac Defibrillator**
  – Early electrical defibrillation correlates best with survival in event of a heart attack

• **Crew Medical Restraint System**
  – Used to restrain the patient so medical treatment can be provided in microgravity
  – Must provide electrical insulation between patient and space vehicle so the defibrillator can be used
For treatment of wide variety of disorders
Absorption of oral medications sensitive to gastrointestinal motility, which may be altered in space
Metabolism of medications (renal, hepatic) may be altered
Alternate routes of administration may be better for some (intramuscular, intravenous, nasal, oral)
There is a wide experience base using oral meds
Shelf life of drug is a significant issue
• For emergency medications and medical equipment where the patient requires immediate treatment to sustain life
• Accessibility and utility strongly influence success/survival
• Medications must be tracked and discarded when shelf-life exceeded
• Medical waste, especially sharp, contaminated needles, must be carefully dealt with
Treatment – Ventilator

• Provides oxygen to a patient which is not capable of breathing for him/herself

• The patient needs to have been “intubated” (have an established airway using a tube in the throat to provide air to the lungs)

• Powered by its own compressed gas supply so no power is required

• If used for more than 48 hours the expired 100% oxygen from the patient quickly enriches the volume of the ISS and breaks fire safety limits
Use of ultrasound for the detection of a collapsed lung

3rd or 4th rib
Space Medical Care System

- Space Medical Care Providers
- Space Medical Care Facility
- Telemedicine Link
- Crew Surgeon
- Engineering Support
- Medical Consultants

Patient
Issues for Surgical Care in Space

- Operator and patient **restraints**
- **Instrument** deployment and fixation
- Surgical **preparation**
  - Ability to gown, glove, and drape
  - Antiseptic agents
  - Increased population of antibiotic resistant bacteria
  - Decreased immune function documented in space
- **Anesthesia**
  - Inhalation anesthetics require liquid-gas interface and closed-loop compartment
  - Migration of the medication towards the head in weightlessness
  - Pharmacokinetics, pharmacodynamics, bioavailability in microgravity
• **Bleeding**
  – Venous bleeding adheres to tissue because of large surface tension forces
  – Arterial bleeding could escape control
  – Control of atmosphere contamination
  – Surgical overhead canopy
  – Laminar flow generation over operative field

• **Surgery**
  – Minimally invasive surgery in lieu of open surgery
  – Organ position shifts
  – Lighting and exposure
  – Decreased proprioceptive sensation
  – Time delay for tele-surgery
Response to an orbital medical event depends on 5 factors:

- **S**everity of illness / injury
- **C**apability of onboard medical system
- **A**bility of surgeon to assist during medical event
- **L**evel of skill / training of **c**rew **m**edical **o**fficer (CMO)
- **E**ase / feasibility of medical evacuation to Earth

Event on lunar or other planetary surface will require a more substantial capability than LEO, where rapid return to Earth is a viable option.
Stabilization

- 3 to 7 crewmembers on ISS
- Crew Medical Officer (CMO) on ISS is usually not a physician
- CMO receives 40 hours of medical training completed at least 3 months prior to flight
- Trained to recognize, treat, and stabilized acute injury
- Trained to prepare patient for transport
Emergency Return on Soyuz

Medical event starts

- 3 hr Stabilize patient
- 1 hr Configure Soyuz and safe ISS
- 1 to 20 hr "Stand & Fight"
- ≥2 hr Loiter in Soyuz
- Soyuz 3.85 g reentry
- Transport to tertiary care center (Germany or Japan)

Medical decision to deorbit

Deorbit burn

Locate & extract

Medical event resolution

>6 hr

15 to 33 hours for 1st Primary Landing Site
The chain of medical care is only as strong as its weakest link

- **Prevention** – Pre- and in-flight medical screening, health stabilization, in-flight countermeasures, and environmental monitoring
- **Diagnosis** – In-flight diagnostic capabilities
- **Treatment** – In-flight therapeutic capabilities
- **Stabilize** – Prepare patient for the stress of transport and the medical capabilities of the vehicle
- **Transport** – Rapid deorbit capability (Soyuz)
- **Definitive Care Medical Facility (DCMF)** – Egress – Extraction by ground forces – Transport – Post-flight rehabilitation


