Session 3
Topic: "Telemedicine"
Wednesday, April 8, 2015
Session 3 Topic: "Telemedicine"

Moderator: Smith Johnston, M.D., Medical Director, NASA-JSC Aerospace and Occupational Medicine Clinics, NASA Johnson Space Center, Houston, Texas.

Discuss the challenges and solutions of providing health care to those stationed in low resource, extreme, and remote environments.

Address the use of telemedicine for remote health care needs, specifically identifying the challenges and solutions involved.

Demonstrate how telemedicine technologies are being applied to solve other operational challenges, and explore the adoption of these techniques across areas where co-development might be mutually beneficial.

The overview will be followed by a Q&A session.
Moderator: Smith Johnston, M.D., Medical Director, NASA-JSC Aerospace and Occupational Medicine Clinics

Speaker Panel:

- Greg Rumph, M.D., Emergency Physician, The University of Texas Medical Branch (UTMB) at Galveston  
  "Capabilities and Challenges for Offshore Medical Care"

- Bob Sanders, M.D., Crew Health and Safety Flight Surgeon, UTMB, NASA Johnson Space Center Neutral Buoyancy Laboratory (NBL), Topic: "Diagnosis and Treatment of DCS in the remotest location: Deep Space and Deep Oceans"

- Sarah Bezek, M.D., Assistant Professor of Emergency Medicine, Baylor College of Medicine  
  "Low Resource Medical Care Delivery Potential for Synergy With Extreme Environment Medicine"

- Victor Hurst, Ph.D., Research Scientist, Wyle Science, Technology and Engineering Group  
  "Future of Space Medicine"

- Eric Richardson, Ph.D., Lecturer, Rice University Department of Bioengineering  
  "Advances in Medical Devices and Relevant Ongoing Development at Rice University"

- Erik Antonsen, M.D., Ph.D., Assistant Professor of Emergency Medicine and Space Medicine, Baylor College of Medicine  
  "Extreme Environmental Medicine and Challenges of Integrating Medicine and Engineering"

- Ashot Sargsyan, M.D., Space Medicine Physician, Wyle Life Sciences  
  "Remote Diagnosis With Limited Capabilities on ISS"
Historic Overview of Space Medicine/NASA and Telemedicine

Nov-1957 – The first use of telemetry in monitoring of a living being (a dog named Laika) by the Soviet Union on Sputnik 2.

Dec-1958 NASA sent a primate named Gordo into Space on a US Army Jupiter missile and recorded biomedical data, which helped demonstrate the launch and ballistic recovery physiologic parameters.

Soviet and US Manned missions monitored environmental and medical/cardiac (ECG) parameters.
- 1964 – NASA/ Integrated Medical and Behavioral Laboratories and Measurement Systems (IMBLMS) which helped expand the measurement systems on the Mercury and Gemini flights
- NASA - Apollo/Skylab – Dr Joe Kerwin, MD, first physician Astronaut
- Advanced Systems for Shuttle and the International Space Station (ISS)

Ground Based Telemedicine Research Activities
- INTELSAT for Apollo - Dr. Michael Debakey’s Surgical work in Early Bird Program 1964
- NASA’s Space Technology Applied to Rural Papago Advanced Health Care (STARPAHC) in 1974 in AZ.
- Armenian earthquake in 1988, with “Space Bridge to Armenia”, then 1990s “Space Bridge to Moscow”, and 1996, “Space Bridge to Russia”.
- American Telemedicine Association 1993
- NASA Analogue Populations (e.g. South Pole)
- Russian, European, and Chinese Space Agencies Mars 500 Project 2011

The Future = Deep Space Ocean 2015!
What NASA Flight Surgeons Do

MCC and SIMs

Mission: Crew health and safety

Space Life Sciences
Exploring Space | Enhancing Life
Spaceflight Effects on Human Physiology

- Dysregulation of the immune system
- Fluid Redistribution to upper body
- Plasma volume decreases, anemia
- Elevated radiation may increase cancer risk
- Otoliths in inner ear respond differently, eyes become main way to sense motion
- Muscle and bone weakening
- Elevated kidney stone risk

The Medical Challenges!
**Background:** Astronauts on long-duration ISS missions have experienced ophthalmic anatomical changes, visual performance decrements of varying degrees and increased intracranial pressure (as measured post flight on 5 crew members).
Possible Contributors to Increased ICP

Fluid Shift

Hypercarbia

Resistive Exercise

Other Factors:
Metabolic, Genetic, Anthropometry

Venous Occlusion

Average Nightly Sleep Duration (hours) - Misaligned versus Aligned

Gender (Males)
Telemedicine
for Low Earth Orbit Space flights
Moderator: Smith Johnston, M.D., Medical Director, NASA-JSC Aerospace and Occupational Medicine Clinics

Speaker Panel:

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   "Capabilities and Challenges for Offshore Medical Care"
Bob Sanders, M.D., Crew Health and Safety Flight Surgeon, JSC Neutral Buoyancy Laboratory (NBL)
   "Field Treatment of DCS - In-water Decompression or Saturation Diving"
Sarah Bezek, M.D., Assistant Professor of Emergency Medicine, Baylor College of Medicine
   "Low Resource Medical Care Delivery Potential for Synergy With Extreme Environment Medicine"
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   "Remote Diagnosis With Limited Capabilities on ISS"
Diagnosis and Treatment of DCS in the remotest locations: Deep Space and Deep Ocean

Bob Sanders, M.D., FACEP
Crew Health and Safety Flight Surgeon, UTMB, NASA Johnson Space Center Neutral Buoyancy Laboratory (NBL),
Disclaimer

• The views expressed in this presentation are mine alone and not necessarily that of UTMB or NASA.

• While I personally have not had DCS,
  – I have seen and treated many cases
Who am I?

1983 Certified Naui & LA County Basic Scuba Diver
1987 Naui Instructor
1990 Began Service With United States Antarctic Program as research Diver (189 Dives)
1993 Joined USC/Catalina Hyperbaric Chamber Crew, Became a DMT
1994 Began Working for Film & Television Industry overseeing Health and Safety including Diving Operations (OSHA standards)
1995 Joined LA County Sheriff Marine Co 217 (Reserve dive team)
2005 Awarded MD degree, EM residency at UPMC Asst Medical Dir., Pittsburgh River Rescue
2008 Medical Officer, Assistant Clinical Professor, U of Hawaii Hyperbaric Treatment Center
2010 Achieved Board Certification in Undersea and Hyperbaric Medicine
2011 Medical Director, American Marine Services Group, American Hyperbaric Center
Similarities between Deep Space and Deep Oceans

- Environmental Control / Habitat
  - Limited Gas
  - CO2 scrubbing
- Physiologic changes
  - Weakness, imbalance
    - Deep Space: fluid shifts & neurovestibular changes
    - Deep Ocean: decreased RBC’s
- If you forget something, that’s bad
- Evacuation is not an option
Differences between

Deep Space and Deep Oceans

• Gravity

• Pressure (up vs. down)
Decompression Sickness (DCS)

• Henry’s Law
  – States gas solubility is directly proportional to the pressure on that gas.
Decompression Sickness (DCS)

Gas solubility in a liquid is directly proportional to the pressure on that gas.

C. Ophardt, c. 2003

Figure 3, Henry’s Law

www.elmhurst.edu
Decompression Sickness (DCS)

Nitrogen coming out of solution, forming into bubbles in body tissues, may result in DCS.
Decompression Sickness

• The diagnosis is difficult at best when the patient is sitting in front of you
  – But...

• 220 miles up or >50 meters below?

• Role of the Medical Director
Prevention

• This is key
  – Single case can cost literally millions of dollars
  – Prevention is key
    • Pre-Breathe (desaturation)
    • Saturation
DCS - Treatment

• Pressure & Oxygen
  – Increase by 2.8 – 6 ATA

• Both are challenges in DS & DO
Limitations to treatment

- Unlikely to have a physician on site
- LIMITED resources
  - BTA (Bends Treatment Apparatus)
    - EMU as Chamber
  - Change habitation pressure or lock out
    - Chamber module in Habitat and change of gas mix
  - Additional staff for hours
- Affects entire mission
Telemedicine

• Used for years in space
• Technology has revolutionized TM
• TM has revolutionized DS/DO
  – Now we can “see” so much more
  – Onsite practitioner can be our hands
• Benefits far beyond the txt of DCS
Future:

• Bringing Deep Space to the Deep Oceans
  – Understanding the human response
    • 1 year mission
    • Twin studies
  – Trends in EMS
  – Ultrasound Use
  – Increased (Confident) use of midlevels
Thank You
Future of space medicine

Victor Hurst IV, PhD
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April 7, 2015
Outline

• Human Research Program (HRP)
  – 6 Elements; Exploration Medical Capability (ExMC)
• What does the ExMC do?
• How does ExMC address health risks for exploration class missions?
• Areas of Interest for ExMC
• HERA
• NEEMO
• MSL
The Human Research Program

NASA’s Human Research Program (HRP) conducts and coordinates research projects that provide human health and performance countermeasures, knowledge, technologies, and tools to enable safe, reliable, and productive human space exploration.

Clay Anderson centrifuges blood samples for a nutrition project aboard the ISS

Example of a study on the effects of center of gravity on performance Neutral Buoyancy Laboratory (NBL) at the NASA Johnson Space Center

TJ Creamer next to the IntraVenous Fluid GENeration (IVGEN) system after it was installed on ISS
HRP Organization & Elements

Divided into 6 major elements:

- Provide the Program’s knowledge and capabilities to conduct research, addressing the human health and performance risks
- Advance readiness levels of technology and countermeasures to the point of transfer to customer programs and organizations

The National Space Biomedical Research Institute (NSBRI) partners with HRP
HRP Organization & Elements

- Behavioral Health & Performance
- Human Health Countermeasures
- Space Human Factors & Habitability
- Space Radiation
- Exploration Medical Capability
- ISS Medical Project
ExMC Element

- The ExMC Element is charged with reducing the risk of “unacceptable health and mission outcomes due to limitations of in-flight medical capabilities” for exploration missions.
What does ExMC do, exactly?

• We’re charged with developing the medical systems for exploration missions outside of low earth orbit
  – We need to understand what is likely to happen (events)
  – We need to minimize the chances of the event occurring
    • Screening, engineering, countermeasures, etc.
  – We need to plan for these events
    • What will we do (training, procedures)
    • What will we need (consumables)
  – We need to take steps to minimize consequences
    • How can we prevent a bad health outcome?
    • How can we prevent a bad mission outcome?
Who works within ExMC?

- **Scientists** – Physiology, Human Factors, Operations, Immunology, Nutrition
- **Physicians** – Aerospace Medicine, Internal Medicine, Emergency Medicine, Physical Medicine & Rehabilitation, Wilderness Medicine, Pain Medicine
- **Engineers** – Aerospace Engineering, Electrical Engineering, Mechanical Engineering, Biomedical engineering, Systems Engineering
- **Project Managers**
Exploration Medical Condition List

- Conditions of concern for exploration missions are identified in the Exploration Medical Condition List
- 2015 list includes 90 medical conditions, from several sources
- “Clinical Priority” assigned depending on the mission
- The medical condition list is a “living document”
- New conditions are added to the list during annual updates
- The priority of conditions on the list may be adjusted as screening, diagnosis, or treatment capabilities change

https://humanresearchwiki.jsc.nasa.gov
### Exploration Medical Condition List

<table>
<thead>
<tr>
<th>Condition</th>
<th>Lunar Sortie Clinical Priority</th>
<th>Lunar Outpost Clinical Priority</th>
<th>NEA Clinical Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulder Dislocation</td>
<td>0 - Not Addressed</td>
<td>0 - Not Addressed</td>
<td>0 - Not Addressed</td>
</tr>
<tr>
<td>Sinusitis</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Skin Abrasion</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Skin Laceration</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Skin Rash</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Smoke Inhalation</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Space Motion Sickness (Space Adaptation)</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Extremity Sprains/Strains</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Stroke</td>
<td>0 - Not Addressed</td>
<td>1 - Should</td>
<td>1 - Should</td>
</tr>
<tr>
<td>Sudden Cardiac Arrest</td>
<td>0 - Not Addressed</td>
<td>1 - Should</td>
<td>1 - Should</td>
</tr>
<tr>
<td>Surgical Treatment</td>
<td>0 - Not Addressed</td>
<td>0 - Not Addressed</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Toxic Exposure</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
<td>2 - Shall</td>
</tr>
<tr>
<td>Upper Extremity Fracture</td>
<td>0 - Not Addressed</td>
<td>1 - Should</td>
<td>1 - Should</td>
</tr>
<tr>
<td>Urinary Incontinence (Space Adaptation)</td>
<td>1 - Should</td>
<td>1 - Should</td>
<td>1 - Should</td>
</tr>
</tbody>
</table>
Capabilities Needed for Screening, Diagnosis & Treatment

- The medical condition list is used to determine the medical capabilities needed for each exploration mission.

- We identify gaps in technology and knowledge.
  - A technology gap results in delivering requirements and/or a prototype system for integration.
  - A knowledge gap results in data or evidence gathered that updates the Exploration Medical Condition List in preparation for the next gap analysis.

- Tasks are assigned to address each technology or knowledge gap.

http://humanresearchroadmap.nasa.gov/
Areas of Interest

Biosensors
Lab Analysis
Imaging
Drug Packaging
Medical Training
Integrated Medical Systems

Biosensors

- Non-invasive
- Wireless
- Integrated sensor suites
- Minimal skin preparation
- Easy to don/doff

Source: http://www.connectedhealthworld.com/products/218
Lab Analysis

- Point-of-care
- Handheld
- Minimal sample preparation
- Reagent shelf life > 3 yrs
- Minimal consumables
- Reusable components

Source: https://technology.grc.nasa.gov/SS-rHealth.shtm
Imaging

- Non-invasive
- Small footprint
- Flexible (software-based) platforms
- Radiation tolerant
- Diagnostic and therapeutic modalities

Source: https://str.llnl.gov/JulAug09/chang.html
Drug Packaging

- Shelf life > 3 yrs
- Minimized drug-packaging interactions
- Compatible with stability testing
- Tolerant of space flight conditions, i.e.
  - Radiation
  - Vibration

Medical Training

- Simulation-based
- Remote guidance with communication delay
- Just-in-time training
- Virtual reality augmentation

Integrated Medical Systems

- Guided medical procedures
- Electronic medical records
- Medical inventory tracking
- Integrated wireless peripherals
  - Biosensors
  - Video conferencing

Other Areas of Interest

- Sterile fluid generation
- Oxygen concentrators
- Sterilization techniques
- Minimally invasive surgical devices

Source: http://www.health.com/health/gallery/0,,20530252_13,00.html
Human Exploration Research Analog (HERA)
Human Exploration Research Analog (HERA)
NASA Extreme Environment Mission Operation (NEEMO)
Medical Simulation Laboratory (MSL)
Medical Simulation Laboratory (MSL)
Summary

• Exploration Medical Capability is an element of the NASA Human Research Program
• ExMC works with various medical and science disciplines to develop the medical knowledge, technologies, and informatics needed for manned, long-duration missions beyond low Earth orbit
• The Exploration Medical Condition List provides the basis for ExMC gaps and research plan
• Evaluation of these medically-related technologies are conducted in various space flight relevant analogs.
Contact

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Advances in Medical Devices and Relevant Ongoing Development at Rice University

Or, What the Medtech Industry can learn from the Aerospace and Oil&Gas Industries

Eric Richardson, PhD
Dept. Of Bioengineering
The Changing Environment

Innovation to lower healthcare costs

Clinical Data to prove the value of therapies

Globalization and focus on emerging markets

3. Ernst and Young Pulse of the Industry: Medtech 2012
The Convergence of Industries

Bioinformatics and Heath IT

Medical Devices and Diagnostics

Drugs and Biologics

Prevention (Primary and Secondary) → Diagnosis → Acute Event → Tertiary Prevention → End of life care
Learning Lessons from Aerospace and Oil & Gas

- A systems engineering approach
- Designing for resource-constrained environments
- Predictive models and simulation
Learning Lessons from Aerospace and Oil & Gas

• Designing for resource-constrained environments:
  – Shortage of trained personnel
  – Lack of Infrastructure
Learning Lessons from Aerospace and Oil & Gas

• Predictive models and simulations
  – Long product development cycles
  – Costly prototypes
  – Challenges to simulate end-use conditions
  – Human lives at stake

“MDIC aims to reduce the time and cost required to develop and approve medical innovation, while improving patient safety, through the consistent application of validated computational modeling and simulation in device development and regulation.” – MDIC.org
Learning Lessons from Aerospace and Oil & Gas

• A Systems Engineering Approach
  – Complex and constrained systems, with the need to make informed trade-offs
  – Developing products to increase the efficiency of the whole system (instead of developing products independently and forcing the system to adapt)
Medical Goals for the Health Maintenance System

- Maintain crew health, comfort, and performance
- Restore crews to health
- Make informed decisions on management and/or triage to:

Design principles – Limited Resource Environment

- Balance utility with size/weight/complexity
- Minimize resupply and sterility requirements
- Minimize crew training needs
- Favor reliability and usability
- Emphasize multipurpose equipment and techniques
Design Process (example of ISS medical kit redesign)

- Define Functional Requirements
  - Hardware selection
  - Engineering Certification
  - Manifest and deliver new hardware
  - New medical capability operational

- Uplink new procedures/training materials
  - Update medical procedures
  - Update crew training
Required Diagnostic Capabilities (examples)

- Ability to evaluate health of crewmembers (periodic or as needed)
  - Expertise: Trained crew medical officer(s) (CMO)
  - Procedures: ISS Medical Checklist
  - Communications: Private Medical Conferences - PMC (AV)
  - No downlink for temperature, body mass, blood pressure, pulse rate, test positivity, and other numerical or categorical parameters (communicated during PMC)
  - Additional guidance: from ground

- Enhanced Diagnostic Capabilities
  - ECG, general imaging in support of a physical examination (use of nonmedical capabilities)
  - Multipurpose Ultrasound (real-time and downlink)
  - Battery of ocular assessment tools: Optical Coherence Tomography (OCT), Fundoscopy, perimetry, tonometry, etc.
  - Limited laboratory tests (hematocrit, urinalysis, blood chemistry)
    - Deep freezer for sample storage
    - Enhanced laboratory capabilities feasible for research purposes
Research
Occupational surveillance
Medical monitoring and/or Dx
Limited-resource AND peculiar environment

- Limited medical capability
- Limited ability to replenish supplies
- Limited training and skills of the providers
- Limited access to “normal” medical facilities

- Peculiar environmental factors
- Modified physiology
- Mission considerations
Ultrasound an ideal modality

- The only universal medical imaging modality in space flight
- No EMI potential, reasonable space & power needs
- Safe, Repeatable, Real-time, Universal
- Compressible/transmittable
- Proven to work in microgravity / space
- Doubles as a powerful non-invasive research modality
BEFORE, NOW, AND AFTER

• **Before:**
  – Crew trained to perform specific tasks independently

• **Now:**
  – Minimal training, reference and refresher tools
  – Remote real-time guidance with elements of virtual presence

• **In the Future:**
  – Minimal training
  – Guidance by technology
    • Integration of US system with vehicle resources
    • Probe position sensing and 3D volume operations
    • Interactive knowledge bank
    • Image recognition – based computer guidance
    • Robotic operation
    • (Possibilities are endless)
Spleen: View 1 of 2

Notes:
- Starting probe position: A6, left side, with the marker toward head.
- Will translate the probe towards the back keeping the probe roughly normal to the skin to find spleen.
- The spleen is often just below the lung, between the ribs.
- Will rotate the probe to find longest image of spleen (long axis).
- May need to translate up or down to avoid ribs.
What is different in space - Imaging Procedure

- *Positioning and restraining*
- *Use of water vs. gel in most applications*

- Remote guidance challenges
  - Discourse - Somebody else is holding the probe for you...
- Altered logic and sequence of image collection
  - Prioritization of views in several dimensions
    - Primary to secondary; Easy to difficult (?);
- Real-time modification of the procedure sequence due to time constraints, operational pressures
What is different in space – imaging results

- Space Physiology context (examples):
  - Chronic fluid shift cephalad
  - Increased venous filling in head/neck region
  - Altered flow patterns in certain vascular beds
  - Altered air/fluid/tissue interfaces

- Pathology:
  - Altered distribution of pathological fluid and gas
  - Lack of evidence for microgravity pathology
  - “Gray zone” between adaptation and disease
  - Maximize the information from US – often beyond the standard “terrestrial” protocols / evidence

- Interpretation: requires additional care/attention and expertise
Imaging Procedures / Protocols we use

Common procedures – “maximized”
Common procedures – modified
New procedures not practiced widely in medical systems
Diagnostic and Research Protocols
Demonstrated / Used in Space

- Abdominal
- Genitourinary
- Central Vascular
- Peripheral Vascular
- TCD
- Soft Tissue
- Thoracic
  - Echocardiography
  - Pleural/Lung
- Musculoskeletal
  - Rotator Cuff
  - Knee, Ankle, Elbow
  - Spine
- Thyroid
- Dental, Sinus
- Eye – Diagnostic
- Eye/Orbit (ICP protocol)
Notable Advances / Contribution Areas

Focused ultrasound techniques for emergency medicine and critical care
Pleural and lung ultrasound, incl. pneumothorax
Eye and Orbit imaging with multipurpose devices
Cardiovascular physiology
Exercise physiology
Telemedicine applications
Medical education
Others
Example: Urolithiasis (urinary stone disease)

• More likely in space flight
• Inherent risk, individual predispositions
• Remote but real possibility of missed small stones during preflight screening

• Small-scale events have occurred in-flight and post-flight
• A major event in spacecraft would be a “mission-impacting event”
Eye/Orbit imaging

- Eye ultrasound tested on orbit in 2003 for trauma
- First imaging on orbit for vision changes reveals some structural changes
- An enhanced surveillance program was instituted
- Conducted in all crewmembers in all mission phases
Musculoskeletal Ultrasound
CONCLUSIONS

• Most current US applications are “space-ready” or “remote-ready”
• Ultrasound plays a great and growing role in
  • Space biomedical research
  • Occupational monitoring and risk management
  • Medical support of illness and injury
  • Design of medical systems for future missions
• NASA remote diagnostic experience is fully transferable to other medical systems
Questions

Car Wash

$1 BILL CHANGER

ONLY IN TEXAS!