South Pole Station: An Analogue for Lunar/Mars Outpost Medical Operations?

Christian Otto, M.D.
2005 South Pole Station Physician
Outline

• South Pole as an Analogue Environment
• Logistics Operations
• Medical Officer Duties
• Clinical Operations & Medicine
• Remote Care: Telepresence & Telehealth
  – Ultrasound
  – Real Time Cases
• Autonomous Care Analogue
• Long Duration Mission Issues
  – Ultraviolet Light Deprivation
  – Psychological Stress & Depression
QUAD 2004

100 and 150 GHz receivers

2.6 meter primary mirror
Single Largest Construction Project undertaken on the Antarctic Continent
Weather for South Pole Station

The date is 08-02-2005 at 04:57 AM

Temperature

-79.3 C  -110.7 F

Windchill

-92.4 C  -134.4 F

Wind

3.0 kts Grid 87

Barometer

659.7 mb (11403 ft)

UTC 08-01-2005 at 16:57 Z

If you want to see official met data - click on this link.
If you want to see South Pole Weather FAQ's - click this link.
Medical Officer Duties

- Patient Care
  - On call 24/7
  - 365 days
- Station Command Structure
- Laboratory
- Radiology
  - Plain Film
  - Ultrasound
- Dentistry
- Psychological Support
  - Counseling
  - Mediator
  - Mid-Season Reviews

Raytheon
Polar Services
Medical Officer Duties

- Aero-medical evacuation
- Telemedicine
- Physical Therapy
- High Altitude Medicine
- Occupational Medicine
  - Safety/OSHA
- MCI Medical Lead
- AED/CPR Training
- Operational Research
  - Isolation & Confinement
  - Telehealth/Telepresence
  - High Altitude
Clinic Laboratory

• Primarily-Point of Care Testing:
  – Complete Blood Counts
  – Renal, Liver Function Tests
  – Electrolytes
  – Arterial Blood Gases
  – Microbiology: Gram Stains, wet mounts
  – Cardiac Enzymes

• Some off-site testing
  – Summer only (Oct-Feb)
• Defibrillator/Pacer
• Physiological monitors (2 ea)
• IV fluid/blanket warming cabinet
• Wall-mounted thermometer, otoscopes, & BP cuff
• Ceiling Surgical Light

• IV Infusion pumps (2 ea)
• Ventilator compatible with air transport
• Hydrotherapy extremity whirlpool
• Trauma Stretcher
• Patient transport gurney
In-patient Ward

- Two bed ward
  - Adjustable inpatient beds & utility headwalls
  - Patient bedside call system

- Additional 2 bed overflow ward
  - Outside “Medical” near general berthing
  - Patient bedside call system
Influenza Cases

Infectivity Curve South Pole Influenza Outbreak

N=64

October 22 - November 27th

C. Otto & R. Shemenski, 2006
Acute Mountain Sickness

- 3 day Acetazolamide altitude prophylaxis
- 75% arrivals suffer AMS symptoms
- 30-50% Visit Medical for treatment
- 10% Require observation or admission
High Altitude Pulmonary Edema
Physical Therapy

- Construction environment
- Long hours, little rest
- Over 100 PT visits to Medical
- Soft tissue: Sprains/Strains/RMI
- Modalities:
  - Heat & cold therapy
  - Ultrasound
  - Interferential
  - Joint mobilization
  - Strength training
  - Soft tissue manipulation
Severe Trauma Occurs at South Pole Summer 2005
International Medical Evacuation-2 of 4
Summer 2005

Chinese National Expedition
at “Dome A”
Dome Argus 4093m
The Highest Point in Antarctica
Medical Evacuation

A. Urgent
  • Immediate Response
  • Unstable

B. Priority
  • ASAP

C. Patient Transport
  • Next available seat

Approximate cost one medical evacuation:

MCM Summer: $5000 (N=45: 2002-03)
SP Winter: 1-1.5 Million (N=3: 1999-03)
### South Pole Medical Evacuation

<table>
<thead>
<tr>
<th>Season</th>
<th>Medevac Class</th>
<th>Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>05</td>
<td>Transport</td>
<td>Depression</td>
</tr>
<tr>
<td>03* Winter</td>
<td>Priority</td>
<td>Cholelithiasis</td>
</tr>
<tr>
<td>02-03 Summer</td>
<td>Urgent</td>
<td>ACS</td>
</tr>
<tr>
<td></td>
<td></td>
<td>AMS/HAPE</td>
</tr>
<tr>
<td></td>
<td>Priority</td>
<td>Ankle Fracture/DVT</td>
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<tr>
<td></td>
<td></td>
<td>Multiple Rib Fracture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urinary Retention</td>
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<tr>
<td>01-02 Summer</td>
<td>Urgent</td>
<td>Cecal Volvulus</td>
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<tr>
<td></td>
<td></td>
<td>Appendicitis</td>
</tr>
<tr>
<td></td>
<td>Priority</td>
<td>Seizure Disorder</td>
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<tr>
<td>01* Winter</td>
<td>Priority</td>
<td>Cholelithiasis</td>
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<tr>
<td>00-01 Summer</td>
<td>Urgent</td>
<td>Fractured Humerus</td>
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<tr>
<td></td>
<td></td>
<td>AMS</td>
</tr>
<tr>
<td></td>
<td>Priority</td>
<td>Acute Low Back Pain</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wrist Fracture</td>
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<tr>
<td></td>
<td></td>
<td>Hemachromatosis</td>
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</table>
Autonomous Medical Care in Antarctica

Population

Onsite Expertise

Enabling Technologies

Antarctic Stations

Communications Technology

The University of Texas Medical Branch
Telepresence Diagnosis & Treatment

- 1999 49y Station Physician-R. Breast lump
- June painful swelling R. axilla
- Critical to determine diagnosis to guide therapy
- 1st remote telepresence diagnostic & telepathology session
- Procedural instructions delivered by real-time VTC

Biopsy performed by non-medical crew member, mass 5.5x4.0cm
Samples imaged digitally at 100X power showed ductal carcinoma
Diagnosis confirmed by cell cytologist NCI Washington, DC
Telepresence Chemotherapy sessions with Indiana University
4 cycles of chemotherapy: Tamoxifen Q3weeks
Monitored for acute drug reaction
Patient evacuated from South Pole October 16th
Digital Fundoscopy & Laryngoscopy
General Dentistry

- Physician serves as Dentist
- Dental Prescreening
- 25 Dental Visits Winter 2005
- Traumatic Fractures
- Broken Crowns
- Pulpitis
- Gingivitis
- Lost/fractured amalgams

Dental Anesthesia

Crown Repair

Traumatic Fractures
Teledentistry
Dental Teleradiology

Abscess
Delayed Fracture Healing

Distal Intra-articular Radial Fracture (Displaced 1-2mm distally)

Disrupted cortical line along radial aspect distal radius

Fracture line

Plain Film Radiograph (oblique view)

Ultrasound Image
Electrical Stimulation of Bone Healing

• Previous Radial fracture resulted in non-union
• Pulsed electromagnetic bone healing device
• PEMF=sustained up-regulation of bone tissue growth factors
• Coil applied over cast at fracture site
• Worn 10 hours/day continuously
• 4 weeks application resulted in normal healing
  – Patient non-tender over site on palpation
  – Pain free motion with resistance
Ultrasound Imaging

- Regular use from 2002-present
- "Real time"
  - US feed through Polycom
  - Radiologist assistance
  - Direct station physicians real-time if necessary
- Review of US exams 2002-03
- Total N=65
- Store & Forward N=61 (94%)
- "Real Time" N=4 (6%)
Classification of Ultrasounds

- Primary US
  N=54 (83%)
- Follow-up US
  N=11 (17%)

Number

Classification

- Abdominal
- Genitourinary
- Gynecology
- Venous
- Derm
- Cardiac
- Endoc
- MSK

- 21.5%
- 21.5%
- 21.5%
- 10.8%
- 9.2%
- 7.7%
- 6.2%
- 1.5%

Raytheon
Polar Services
South Pole Telepresence Echocardiogram

- 26y Male acute respiratory distress, Rapid onset pyrexia & dysphagia
- Concern with compromised airway, epiglottitis? Laryngoscopy=normal epiglottis
- Required 17 liters IV fluids in 36 hours. CXR normal. +WBC
- 5 day inpatient stay. Rx I.V. Rocephin Ddx: Tracheitis vs atypical pneumonia
- Chronic fatigue, persistent tachycardia, dyspnea & hypoxia persists 4 weeks
- Nonspecific EKG changes. Concern re: myocarditis
- Standard Cardiac echo sent “store & forward”
- Concern over posterior mitral valve leaflet
Effect of Ultrasound on Patient Care

<table>
<thead>
<tr>
<th>Effect of US on Treatment</th>
<th>No. Cases</th>
<th>Proportion (%)</th>
<th>Rank</th>
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</thead>
<tbody>
<tr>
<td>Prevented aero-medical evacuation</td>
<td>16</td>
<td>24.6</td>
<td>1</td>
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<tr>
<td>Further Investigation</td>
<td>15</td>
<td>23.1</td>
<td>2</td>
</tr>
<tr>
<td>Prevented unnec treat/Invest</td>
<td>15</td>
<td>23.1</td>
<td>2</td>
</tr>
<tr>
<td>Caused new treatment</td>
<td>14</td>
<td>21.5</td>
<td>3</td>
</tr>
<tr>
<td>Confirmed current course of treatment</td>
<td>11</td>
<td>16.9</td>
<td>4</td>
</tr>
<tr>
<td>Resulted in add. specialist consultation</td>
<td>8</td>
<td>12.3</td>
<td>5</td>
</tr>
<tr>
<td>Contributed to Medevac?</td>
<td>7</td>
<td>10.8</td>
<td>6</td>
</tr>
<tr>
<td>Changed quality of treatment</td>
<td>1</td>
<td>1.5</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>87</strong></td>
<td></td>
<td></td>
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</table>
Two-year Review of all Telehealth Consultations

- All three USAP stations (02’-04’)
- 117 consultations in 15 medical specialties

<table>
<thead>
<tr>
<th>Method of Consultation</th>
<th>Store &amp; Forward</th>
<th>Real-Time</th>
<th>Voice-Link</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>62.4%</td>
<td>22.2%</td>
<td>14.4%</td>
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</table>
In a groundbreaking telemedicine development, doctors in Massachusetts earlier this month helped a physician at Amundsen-Scott South Pole Station to surgically repair the damaged knee of a meteorologist spending the winter in Antarctica.
# Station Inaccessibility & Telehealth Consultations

<table>
<thead>
<tr>
<th>Station</th>
<th>Consult Rate</th>
<th>Consults/Patient</th>
</tr>
</thead>
<tbody>
<tr>
<td>South Pole</td>
<td>3.4%</td>
<td>4.0</td>
</tr>
<tr>
<td>Palmer</td>
<td>2.5%</td>
<td>2.1</td>
</tr>
<tr>
<td>McMurdo</td>
<td>0.5%</td>
<td>1.2</td>
</tr>
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</table>
South Pole: Autonomous Care Analogue

Communications Delay & Abort to Earth

ISS: 1sec/25-32 hours

Lunar Surface: 2sec/72 hours

South Pole: 1sec/2-3 Weeks (Winter)

Martian Surface: 40min/6 Months

• Telehealth Technologies
• Remoteness=Increased Consultation
• Majority Consults Store & Forward
• Crew Medical Officer Key Role
Vitamin D & Mental Health

- Association between reduced sun exposure & mental illness
- Receptors for Vit-D found in nucleus of brain cells
- Involved in manufacture of neurotransmitters: serotonin, dopamine, NE
  - decreased levels involved in depression

- Subsyndromal seasonal affective disorder in Antarctica Palinkas L.
  - Mid winter & late winter mood scores significant correlation to station latitude

- “Vit-D Enhances Mood in Healthy Subjects in Winter” Lansdowne AT.
  - SAD may be associated with depressed levels Vit-D
  - Vit-D group significantly enhanced mood
Severe Ultraviolet-B Deprivation
March-September

UV-B (290-320nm) Irradiance
South Pole, Antarctica (90°00' S)
local apparent noon
Vitamin D Supplementation & 25OH Serum Levels at Sunset & Sunrise

<table>
<thead>
<tr>
<th>Vit D Dose IU</th>
<th>25OH nmol/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sunset</td>
<td>Sunrise</td>
</tr>
</tbody>
</table>

C. Otto, R. Shemenski & R Veith, 2006
Monthly Percentage of South Pole Winter-Over Population Presenting with Clinical Depression: A Twelve Year Analysis (94-05)
South Pole-Depression Incidence

- Total winter-over personnel 94-05=543
- Depression incidence=2.03% \(\frac{11 \text{ depression cases}}{543 \text{ persons}} \times 100\)
- Winter-over period=221 days
- Total person days=120,003 \((543 \text{ persons} \times 221 \text{ days})\)
- 11 cases of depression total
- 1 case every 10,909 person days
- Average winter-over crew size=45
- 1 case depression every 242 days, or every 1.1 winter seasons \((\frac{10,909 \text{ person days}}{45 \text{ persons}})\)
Modeling Depression Incidence for Lunar/Mars Outpost Operations?

- **Outpost Operations:**
  - 6 person crew (10909 person days/6 crew)
  - 59.6 months
  - One case of depression every 4.97 years

- **Limitations & Assumptions:**
  - USAP Crew Selection & Screening Process does not match vigor of NASA selection process
  - USAP psychological countermeasures do not match NASA support of long duration space crews
  - Suggest lower rate of clinical depression than 2.03%
  - South Pole Isolation 8-12 months vs 26 months on Mars Mission***
  - Degree & risk of isolation & confinement for Lunar/Mars Outpost operations greater than South Pole
  - Suggest higher rate of clinical depression than 2.03%

- **Selection, Training & Countermeasures**
Monthly Incidence of South Pole Winter-Over Personnel Presenting to Medical with a Psychological Diagnosis: A Twelve Year Analysis
(Depression, Adjustment, Anxiety, Counseling, Insomnia)
Stress Response Profile Interpolation: 6 Month ISS Mission with 8.5 Month Winter-Over Polar Mission
Stress Response Profile Extrapolation: Mars Mission-15 Months

15 Months: ½ Mars Mission

8.5 Month Polar Mission

6 Month ISS Mission

ISS “Third Quarter”
Summary

- South Pole as an Analogue Environment
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  - Ultrasound
  - Real Time Cases
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- Long Duration Mission Issues
  - Ultraviolet Light Deprivation
  - Psychological Stress & Depression
Questions?

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