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Telemedicine During Lunar-Mars Life Support Test Project Phase III

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ABSTRACT

Evaluation of crewmembers participating in previous closed-loop life support tests have revealed symptoms/signs (e.g., mucous membrane irritation) in crewmembers from elevated concentrations of noxious chemicals off-gassed from support structures. Improved means of monitoring, evaluating, and treating the isolated crew was sought for the Lunar-Mars Life Support Test Project (LMLSTP) Phase III test, in addition to providing support for several planned medical experiments. The Telemedicine Instrumentation Pack (TIP) was utilized to provide: 1) real-time medical care, 2) medical monitoring, and 3) science evaluation during the LMLSTP Phase III 90-day study. The TIP was found to be effective in assessment of the medical findings, resulting in prompt recommendations for management of conditions/injuries sustained during operations, and was highly effective in monitoring the crew for signs of contained atmosphere effects and acquiring medical science data.

Introduction

For humans to venture to other planetary bodies for extended-duration missions, a life-sustaining environment must be brought with, or pre-positioned for, the space travelers. There are no known extraterrestrial locations that provide all of the essential ingredients, in an immediately usable form, for human existence. Therefore man must build a habitat to provide the elements of life during his journeys and upon his arrival to the planetary body. In providing a space-qualified home for crews that closes the atmospheric, water, and energy loops (i.e., a closed-mass system), the habitat must provide: the proper balance of oxygen/nitrogen, carbon dioxide scrubbing/recycling, sustainable nutrition, potable water, waste elimination/recycling, etc. This closed-mass system must operate indefinitely without resupply from Earth – so it must recycle or regenerate all necessary elements for life and ensure these elements are safe for human existence.

There is the potential for accumulation of toxic levels of many substances within the confines of the habitat. These noxious and possibly harmful substances may be components of the habitat structure that become volatile with pressure changes or over time, or they may be produced by the recycling/reclamation process itself. It is the responsibility of the space medical team to ensure that the environment is routinely monitored for levels of possible harmful agents and that the crewmembers are monitored for signs of toxicity. The medical team also conducts routine health evaluations of the crew to maximize its performance in the extreme environments of planetary exploration.

Two goals of the medical operations participation in the LMLSTP Phase III project include:

1) the evaluation of training and use of the Telemedicine Instrumentation Pack (TIP) (Figure 6.1-1) by the Crew Medical Officer (CMO) and NASA flight surgeons for isolated long-duration crews, and
2) the use of the TIP, during isolated chamber stays, to support medical and life science research evaluations requiring serial crew physical examinations.

Figure 6.1-1 *The Telemedicine Instrumentation Pack*

The objectives of the TIP telemedicine evaluations by CMO to flight surgeon are:

- To evaluate the CMO training plan for TIP use in an isolated environment
- To evaluate the quality of the TIP physical examination imaging capabilities performed by nonphysician CMOs, as a preparation to DSO 334 which was scheduled to fly aboard STS-89 (January 1998)
- To understand the flight surgeon interaction requirements with the CMO, in order to obtain diagnostic or high-clinical utility images
- To test the limit of diagnostic accuracy of the TIP hardware by screening for signs of airborne mucous membrane irritation, injuries, and other clinical events
- To evaluate the use of the TIP in evaluating and following contingency medical condition (e.g., skin wounds) during periods of chamber isolation.

The objectives of the use of the TIP in supporting medical research in isolated crew chamber studies are:

- To assess the TIP's utility in accurately assessing skin responses for immune function testing, as a prelude to a follow-on study of immune status proposed for long-duration space flight
- To assess common indications of external physical signs of nutritional status using the TIP.

Planned medical operations research evaluations during LMLSTP Phase III are:

- Cell-mediated immunity in an isolated environment
- Space Flight Cognitive Assessment Tool and behavioral health assessment tool evaluation
- Behavioral trends and adaptation during space analogue missions
- Assessment of sleep quality during space flight simulations
- Habitability review using "SOIRT," the Space Operations Issues Reporting Tool
- Monitoring latent virus reactivation and shedding
- Evaluations of nutrition, noise, bone metabolism, exercise countermeasures, food systems, and bacterial biofilms.

Other objectives include:

- Comparisons of methods for remote training
- Portable Clinical Blood Analyzer – just-in-time training evaluation
- ISS Medical Kit, training, Telemedicine Instrumentation Pack/techniques validation.

Finally an assessment of the requirements for future chamber-type test bed medical support is to be acquired as a result of lessons learned from this LMLSTP study.

Methods

TIP Prechamber Entry Training

A two-hour session with the crew and trainers was conducted, led by Dr. D'Aunno reviewing immune response study design and rationale, procedures for subcutaneous application of antigens, and response measurement technique. No time was scheduled to provide the nonmedical CMOs with training for recognition of pathological conditions of the human body or even for normal immune responses to antigenic challenge in the integument. Therefore the CMOs were trained in observation techniques and were instructed how to visualize and palpate expected findings on the skin and mark the findings with a supplied nonpermanent marker.

A two-hour session was conducted with Drs. McGinnis and Jones, Ms. Cheri Armstrong, and Mr. Scott Simmons to train on deployment, configuration, operation, and stowage of the TIP and techniques for utilizing the various lenses, ophthalmoscope, and otoscope attachments. The CMOs were shown the techniques for:

- acquisition and verification of the nature of images of:
  - the skin – with the macrolens feature
  - the exterior eye and conjunctiva
  - the interior eye – lens and retina
  - the external ear canal and tympanic membrane
  - the nasal mucosa
  - the buccal mucosa, palate, and uvula
- placement of ECG electrodes and activation of the tracing acquisition software
- placement of pulse oximeter for obtaining O_2 saturation readings
- placement of the electronic stethoscope in appropriate anatomic locations for acquiring physiologic heart and lung sounds
- basic first aid provision

Examinations of the crewmembers were conducted on two occasions for general health assessment and to evaluate the possible effects of the atmospheric environment on chamber days 30 and 60. The skin examinations for immune function were also performed simultaneously with the general health examinations.

Evaluations of the TIP hardware performance, the video image quality, and the utilization protocols were conducted concurrently with the examinations. The CMOs performed the TIP examinations on one another on chamber day 30 in the wardroom area, as shown in Figure 6.1-2.

Figure 6.1-2 *The CMOs and TIP in chamber; deploying the macrolens*

Contingency examinations were to be conducted as needed but, in this study, were performed concurrently with the general examinations.

Flight surgeons and technical support personnel set up a telemedicine workstation in Building 7, external to the LMLSTP chamber, and monitored the examinations with direct video monitors from both the mounted internal chamber cameras and the video images generated by the TIP camera chip. Audio connections provided real-time feedback between the flight surgeons and CMOs (see Figure 6.1-3).

Figure 6.1-3 *The flight surgeons at the workstation outside the chamber*

Findings

The CMO training sessions were brief, but due to the user-friendly nature of the hardware and the well-formulated protocols for utilization, the CMOs rapidly acquired the skills required for effective deployment and operation of the TIP. Queries of the CMOs revealed that they felt well prepared for conducting examinations utilizing the TIP. They also felt well prepared to perform the periodic immune system study evaluations and were at no time uncomfortable with the procedures or observation techniques that they learned.

Acquisition of Data/Images in Performing the Evaluations

Image quality – The images obtained during the hardware evaluation and while performing the immunologic examinations in general were very good and were considered by the flight surgeons to be of diagnostic quality. There were several incidents of interference lines, generated by simultaneously operating electronic equipment, obscuring the video images. Interference suppression was felt to be important in preventing future such obscurations (see Figure 6.1- 4).

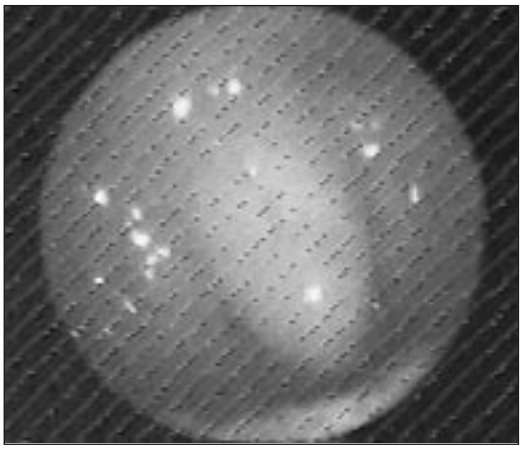

Figure 6.1-4 *The uvula and palate with significant interference in the NTSC, or video, signal*

Flight Surgeon/Crew Medical Officer interaction – A key to the ability of the crew to provide the flight surgeons with quality imaging, with the limited CMO training, was real-time feedback from transmitted images and data to the CMO performing the examinations. The flight surgeons had no delay in communication in this evaluation and therefore were able to provide instant feedback for position of camera lenses, oto- and ophthalmoscopes, and TIP instrument settings. The flight surgeons' feedback to the CMO allowed acquisition of images that were of maximal diagnostic value, without the need for later review and reacquisition of images that may have been suboptimal, e.g., if a "store and forward" methodology had been utilized. An example of the assisted image acquisition can be seen in Figure 6.1-5, where the tympanic membrane is visualized in motion during a Valsalva maneuver.

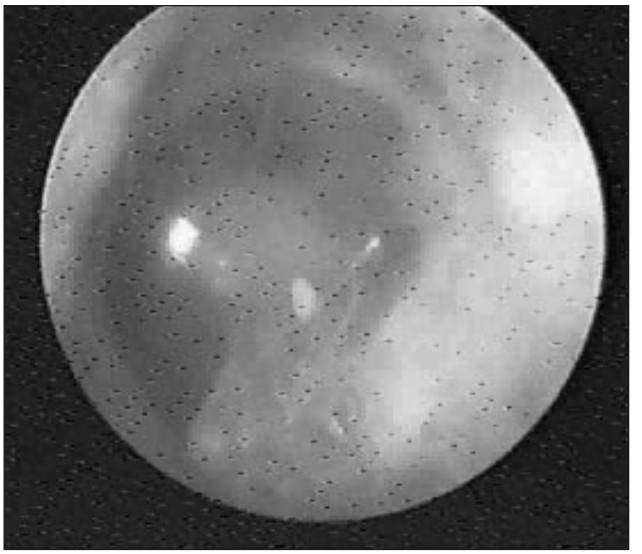

Figure 6.1-5 *The tympanic membrane, during the CMO otoscope examinatio*n

Mucous membrane assessment – The flight surgeons felt that they were able to adequately view the crew's mucous membranes for signs of injury or toxic effect from the video images provided by the CMO via the TIP. In the Phase III test, no signs of adverse effect from off-gassed agents were detected by the medical surveillance. However, several superficial linear lesions were noted in the nasal mucosa of one crewmember examined, which were felt secondary to the chamber's reduced relative humidity during the period preceding the examination (see Figure 6.1-6).

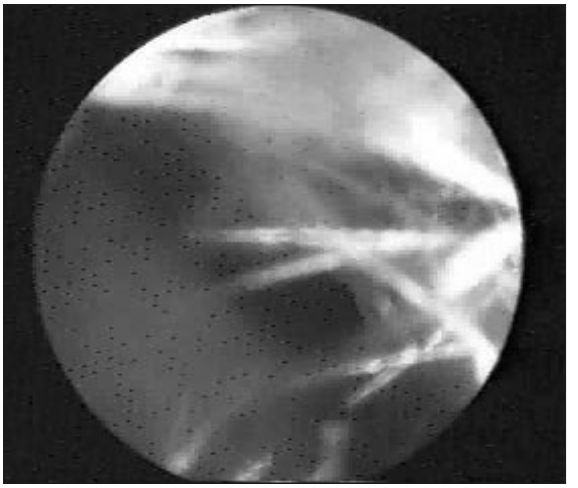

Figure 6.1-6 *The mucous membrane showing a small area of hemorrhage*

Contingency medical management – A superficial laceration of the mid-anterior tibia was sustained in one crewmember as a result of striking the lower leg on the metal stairs between levels in the chamber. The wound was evaluated by the macrolens of the TIP and found by flight surgeons not to require suturing. It was treated with steristrips, topical antibiotic ointment, and dressing (see Figure 6.1-7). The wound was followed on a subsequent exam and found to be healing well, with no evidence of infection. The TIP provided excellent images for inspection, assessment, and treatment recommendations for this minor medical contingency situation.

Figure 6.1-7 *A skin wound (shown here after treatment) incurred during chamber operations*

Immune function evaluation – The flight surgeons were easily able to visualize the sites of antigen application on the ventral forearm of all study crewmembers (see Figure 6.1-8). Erythema, when present, was easily discernable. The flight surgeons relied on the palpation skills taught to the CMOs for assessment of induration, but they were able to give real-time feedback to the measurements of both erythema and induration through the video and audio connections at the flight surgeon's external workstation.

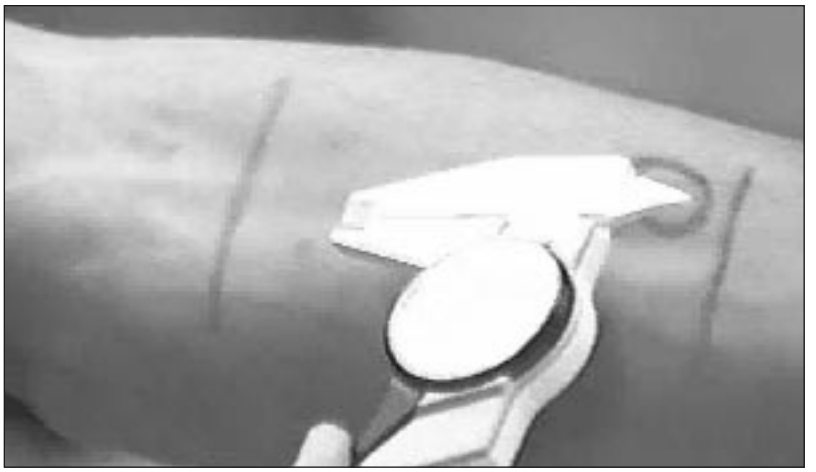

Figure 6.1-8 *Immunization site surveillance*

Nutritional assessment – Views of triceps skinfold measurements, as well as inferior conjunctiva for signs of anemia, were easily accomplished with the aid of the CMO-operated TIP.

Difficulties Encountered

Due to conflicting requirements in developing the flight hardware for STS-89, the 2X filter was not available to the Phase III chamber crew at the time of testing in the chamber, which made focusing on the skin surface more challenging for the CMOs.

The retinal images, with dimmed lighting but no pupillary mydriatics, are difficult to obtain, even with a highly trained user of the TIP ophthalmoscope. This hardware item may require additional modification to make the device more user-friendly, as the images were not as sharp and useful compared with the other examination images obtained during the study.

Episodic interference occurred with broadcast video imaging.

Conclusions

Accurate skin response measurement data was obtained with high confidence by the investigator, because the TIP was used to supervise the measurements real-time from a remote flight surgeon workstation.

The CMOs performed above expectations in operating the TIP hardware, especially considering the limited training, and were able to provide the flight surgeons with quality physical exam information.

Real-time or near real-time audio exchange capability was invaluable in directing the CMO while performing the examination in order to obtain the desired images.

The images obtained were adequate to make real-time diagnostic decisions based on visual appearance of the mucous membranes (e.g., an intranasal hemorrhage lesion was identified following a night of low-humidity sleep, tympanic membrane motility could be observed during a Valsalva maneuver, etc.).

RECOMMENDATIONS

The video interference problem should be evaluated and corrected for telemedicine support of future advanced life support studies and other test beds. In addition, with a permanent crew already aboard the International Space Station, real-time or near real-time video and audio communication capability with flight surgeons should be provided for crew health evaluation including contingency physical examinations. Plan to have a dedicated medical workstation inside future test bed facilities to provide a more robust medical evaluation and treatment capability for long-duration isolated chamber crews, and to serve as a test bed for newly developed medical equipment technologies and for validation of devised protocols for medical evaluation and care delivery. Finally, operational evaluations of the "store-and-forward" methodology for image acquisition should be performed, with a communication delay for feedback on the images, as would be required in an actual Mars mission medical scenario.