How NASA Uses Telemedicine to Care for Astronauts in Space

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TECHNOLOGY

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Since the Expedition One launch to the International Space Station (ISS) in 2001 — the first long-duration stay on the orbital construction site — NASA’s Human Health and Performance team has been developing expertise in the planning and provision of medical support to crews staying in our world’s most remote environment. Four times each year, we launch a new team of astronauts and cosmonauts to the ISS, where they will stay for six months to one year, performing engineering tasks, research, maintenance, and upgrades to prepare for future commercial vehicles. During this amount of time, access to medical care is crucial, as altered routines and microgravity have deconditioning effects on crew members’ bone and muscle, fluid distribution, and immune function.

Telemedicine is a key component of medical care on ISS. While doctors have always communicated with the crews of short missions, largely to guide them through acute spaceflight-specific health issues, today’s long-duration and exploration missions require space medicine to fulfill a much wider-ranging mandate and extend beyond minor illness and urgent care. Telemedicine enables preventive,
diagnostic, and therapeutic care during many months in space, and ideally allows for seamless
continuity of care before and after missions. But our experience shows that achieving this requires
planning and training prior to launch, as well as good communication and rapid learning in space.
These factors are important for realizing the potential of telemedicine to improve care in other
remote, extreme, or otherwise resource-constrained environments.

**Planning the medical support of each mission.** The medical capability in a given space flight program
(e.g., Apollo, Skylab, ISS, etc.) is defined by its medical requirements. Medical care for each mission
within the program is planned by NASA’s ground medical team of doctors, biomedical engineers
(BMEs), nurses, imaging specialists, and psychologists. There is careful consideration of the “mission
profile,” a broad set of factors that influence health and medical needs and risks, such as flight
duration, launch and landing modes, medical evacuation capability, and time to definitive medical
care.

They determine what material and intangible means of disease and trauma prevention, diagnosis,
and treatment are needed for each mission. Medicines, instruments, consumables, and exercise
devices belong to material assets; intangible assets involve medical expertise on board and on the
ground, processes, procedures, and protocols. Telemedicine capability brings these together with a
well-planned and tested communications system that securely moves medical data, other
information, and expertise in both directions as needed.

**Training crew members to manage their care.** Before launch, all astronauts are trained to use the
medical assets that will be on board. There is not always a doctor on board, so some astronauts also
undergo 40 hours of paramedic-level training to qualify as a crew medical officer. They become
familiar with a checklist of foreseeable medical problems and emergency responses, such as a
crewmate having difficulty breathing. They learn how to perform a periodic basic physical
examination and how to handle the most common medical problems, such as motion sickness, skin
irritation, and back pain. Over 60% of astronauts experience back pain in space as their spine
lengthens and straightens upon arriving on orbit. After training, they’ll know they can either call
their flight surgeon, who might direct them to a drug in the medical kit, or use a procedure to relieve
the pain.

Over the course of several launch cycles, a group of physicians, nurses, and pharmacists will
periodically evaluate NASA’s procedures and medical kits to bring them up to date with the most
recent best practices in both terrestrial and space medicine. For instance, when the American
Hospital Association removed the medication Lidocaine from the simplified Pulseless Arrest
Algorithm (used to resuscitate someone), NASA flight surgeons removed it from the medical kits on
orbit and the ISS Advanced Life Support procedure. Astronaut training and software-based
procedures changed accordingly to ensure the most current and effective medical care was available.

**Good communication and rapid learning is essential.** Astronauts, doctors, nurses, and Mission
Control personnel learn to acquire good operational communication skills through classes, practice,
and scenario-based simulations. They learn how to communicate about and address a range of medical concerns. In emergency scenarios, such as an astronaut choking, a crew member will rely on training and onboard procedure files to address the problem immediately. At some point after the emergency, and for less critical medical issues, the crew will establish a private medical conference with a doctor on the ground to discuss the best course of action and follow-up. A BME sets up a secure connection for the doctor to videoconference with the astronaut and direct all aspects of patient evaluation, situation assessment, and treatment. Occasionally, a specialist will be consulted and tied into the conference to assist with diagnoses or treatments. Our experience has demonstrated that shared knowledge and training, combined with a reliable private communication link, leads to the best care.

**A Case Study: Conducting Ultrasounds in Space**

Telemedicine in action can be best described through an example: In the middle of a six-month mission, an ISS crew member with history of knee injury (who was symptom-free before the mission) developed bothersome knee pain when training on the resistive exercise device that all astronauts use on board. When pain persisted for two days and occasional acetaminophen and ibuprofen were no longer effective, a private medical conference was arranged between the astronaut and a NASA physician on the ground. The physician requested an ultrasound examination of the affected joint.

Ultrasound imaging, for the time being, is the only medical visualization device that can be flown and operated on a spacecraft. The technology is radiation-free, versatile, cost-effective, and easily repeatable, and its results are more reliable and less operator-dependent than techniques such as computed tomography and magnetic resonance imaging.

NASA ultrasound specialists guided the crew step-by-step through a comprehensive imaging procedure. They were also assisted by a remotely located orthopedic radiologist (connected through virtual private network), who could view the ultrasound imaging stream in real time and offer a preliminary impression. After reviewing the full set of imagery (downloaded from the ISS within the hour by the BME), the radiologist confirmed the problem. The astronaut was then prescribed a temporary reduction of exercise loads and some medications. He was soon able to return to the normal exercise routine, and he completed the mission without difficulty.

In this example, a specialized procedure of targeted ultrasound imaging was used to augment a clinical assessment with objective information for accurate decision making. The procedure would not be possible without telemedical remote guidance by an experienced ultrasound “guider” on the ground, and could be incomplete without additional expertise from the remote radiologist. Effectiveness also depended on the crew receiving premission conceptual training, learning basic imaging skills in practice sessions, and remaining intellectually engaged throughout the procedure.

While ultrasound remains the most practiced and well-developed telemedicine procedure, this approach would hold true for other “guidable” medical procedures as well, such as a dental procedure, minor surgery, or acupuncture. The remote guidance paradigm works in remote care.
scenarios wherever imaging technology and internet connectivity are available but local expertise is lacking. It is being successfully applied in an increasing number of rural, expeditionary, and military medicine settings where lightweight, deployable equipment can be operated through an easily adaptable procedure, as long as there is a reasonably stable internet connection.

NASA’s experience with telemedicine can be applied not only to remote environments like Antarctica but also to areas currently underserved by medicine, from rural areas in the United States to developing countries. As technology and the internet become more accessible, telemedicine will increasingly connect health care providers to underserved areas. Since specialists concentrate in larger cities, this technology infrastructure, combined with telemedicine best practices, will improve disparities in health care.

In the meantime, we are taking what we’ve learned about telemedicine to figure out how we will deliver care on future interplanetary missions, which will no longer have instantaneous communications and will require guidance to be provided by onboard computers, artificial intelligence, and virtual reality software. While the communication links between the ISS and Mission Control operate in near real time, allowing step-by-step guidance of the onboard operator, a Mars mission would entail a delay of minutes, which would render remote guidance impossible and therefore require the necessary knowledge banks and guidance tools to be placed on the vehicle ahead of time. Space exploration, again, may help create new solutions that will eventually enhance medical care on Earth.

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