Space Medicine: Past, Present, and Future Issues

J. D. Polk, *Johnson Space Center*

Where do you start when your country wants you to go back to the moon and on to Mars? You start with where you have been and look at where you are now operationally. You must define the concept of operations and the levels of care. You also must understand the six tenets of flight medicine: mass, power, volume, time, money, and risk.

The mass you can carry is limited; launch cost is $10,000 to $20,000 per pound. The usable power and available volume are also limited. Crew member time is similarly limited, and so is the available money. The risks are very real, and we have to lower them. As we look at how to solve our medical innovation issues, we have to consider constraints and tradeoffs. (If you want your medical project to succeed, it should not increase more than two of these, and preferably should reduce at least one. – Polk's Law)

Originally we were not sure what would happen to people in space, and what we did learn, we did not easily share. Other countries were competitors, not partners. We selected crew members from a very specific type of individual, and their flights were very short – often lasting a few days. The average age for Apollo crew members, for example, was 36; the average age of members in today's Astronaut Corps is 46. We operated differently in the Apollo days.

While early crews consisted primarily of fighter pilots, today's crews now include scientists, educators, and people from many other backgrounds. The psychological makeup of these crews necessarily differs, too. Missions are longer, measured in weeks and months, and crew members can return to a planet that diverges socially from the one they left. For example, one cosmonaut left the USSR and, when he landed, his nation's form of government had changed.

Some key components of our current medical support system on orbit are: the ambulatory medical pack, containing mostly over-the-counter drugs and medical supplies; the advanced life support pack, which has more powerful drugs and supplies and can perform ultrasound; flight surgeon support (remotely, on console); and three exercise devices – the Cycle Ergometer with Vibration Isolation System; the Treadmill with Vibration Isolation System; and the advanced resistive exercise device.

NASA's overall flight medicine strategy is to practice offensive preventive medicine. This approach (and the bioastronautics research that supports it) massively reduces our risk, our cost, and the volume of what we have to fly. This overall strategy can be broken down into three primary preventive strategies.

Primary preventive strategy: *selection standards for crew*. We are extremely careful when choosing astronaut candidates.

Secondary preventive strategy: *fitness for duty and medical requirements*. We scan crews for long-duration issues (e.g., scans discovered a tumor in a crew member's pituitary gland that would have led to optic nerve problems). It is not cost-effective to discard astronauts once we have spent $1M to train them; at that point it is far easier to fix any problems they have.

Tertiary preventive strategy: *in-flight mitigation and treatment.* We fly therapies to treat the remaining risk.

Other factors that support this approach on the clinical side include quality and consistency, patient information dataflow, occupational health surveillance, and focused operational research and development. Because a lean Six Sigma practice has standardized guidelines of care, we focus on standardized electronic medical records (essential when crews train in Russia for a number of months), produced a SharePoint warehouse for mission data, maintain the Lifetime Surveillance of Astronaut Health, and created the Life Sciences Data Archive to preserve our lessons learned. NASA needs innovations and alliances in treatment processes and how we attack things on orbit, but the best thing we can do is to fly a healthy astronaut.

How does all this help space flight – and NASA's partners? Below are two examples.

Example 1: A closed-circuit ventilator with oxygen concentrator

This device was created as part of a partnership among NASA, the department of Defense (DOD), business, and academia. We focused on this problem for a number of reasons. If an ammonia release takes place on orbit and a crew member must be intubated for ventilation, that oxygen could leak into the cabin and

elevate the fire risk. The project created a closed-loop ventilator with net environmental oxygen change zero, in addition to saving the mass and volume of many bulky oxygen bottles. This device provided parallel benefits to DOD (i.e., to also not have to fly heavy, bulky oxygen bottles), and could potentially change care in small hospitals that have neither the time nor the space to support a more conventional solution.

Example 2: Crew physiological observation device

Fig. 1. *Crew physiological observation device.*

The NASA Ames Research Center developed a small (the size of a BlackBerry®) and light device for a belt carrier – the crew physiological observation device (CPOD) – that transmits ultrasound and EKG [electrocardiogram] data to the heads-up display (figure 1). We tested the CPOD and expect it to be available for use in private practice in about 10 years.

How do we start planning for the medical side of exploration?

To plan for the medical side of exploration, we must first answer the following questions:

What is the risk?

What are the medical diagnoses unique to space flight or astronaut populations?

What is the best mitigation strategy? Is it prevention, prophylactic surgery, genetic screening, flying a physician on the mission, or perhaps some combination of these?

Remember the six tenets of flight medicine and the constraints we have to work under. The higher the capabilities we fly, the lower the risk; but we cannot eliminate all risk, and we cannot fly all of the potential capabilities. Risk equals severity times probability, so we take the middle road of accepting some risk and fly capabilities and mitigations to reduce the remaining risks.

In the near future, NASA faces a number of unique aspects. The distance of Mars from Earth (20+ minutes communication time, 6+ months travel time) changes things. In-situ production of consumables and sustainability of power have never before been required on NASA missions. On future Exploration missions, crews will have to be relatively autonomous. We will also have to reverse the "life-limb-mission" paradigm. If a crew member in low-Earth orbit sustains an injury or becomes ill, it is possible to bring that crew member down for treatment of the injury or disease. On Exploration missions, it is a different story; we cannot fly all six crew members the several months back from Mars to treat one crew member's injury or disease. Triage thus becomes important.

The building blocks of Exploration clinical medicine will be modular; we will build on our hardware and our capabilities. We will fly equipment to the moon and leave it there, continuing to add to it. NASA is building toward 6-month lunar missions and 24-month Mars missions. But what levels of care are possible on these missions, and where do we have to stop? These are tough triage decisions. Common things occur regularly, and all space-flight-unique medical maladies as well as residuals are not necessarily screened out. What is possible is not always feasible, and is often limited by consumables.

NASA is leveraging experience from all of its past experiences, including Apollo, Skylab, shuttle, *Mir*, and the International Space Station (ISS). Flight analogs are Antarctic stations, submarines, and NEEMO [NASA Extreme Environment Mission Operations], an underwater center off the coast of Florida. We forecast, based on previous experience, our concept of operations, Delphi, flight tolerance, probability, and mitigation.

The concept of operations for Exploration medicine is clear. It takes 6 months to travel from Earth to Mars in microgravity. Six-month flights aboard ISS have allowed us to learn the issues there. The moon is at 1/6g; will our strategies and healing processes work in reduced gravity? The lunar missions will provide the necessary proof of concept to see whether those processes will work on the 3/8g of Mars.

Click here for next report