Imaging in Space Exploration

M. Castillo

*AJNR Am J Neuroradiol* 2012, 33 (2) 201-202
doi: https://doi.org/10.3174/ajnr.A2795
http://www.ajnr.org/content/33/2/201

This information is current as of August 8, 2024.
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I remember the amazement I felt when man walked on the moon. Today, I feel that monies spent on space exploration would be better used in green energy and ocean preservation programs. We already live on earth, the most perfect spaceship of all: Why go beyond it? Regardless of my feelings, space exploration will continue, funded either by governments or private industry. For example, for only US $200,000 (a deposit of $20,000 is required), you can book a suborbital space trip on Virgin Galactic; 340 places are already reserved and paid for.

If you want to experience microgravity cheaper, you can go to Las Vegas and fly the “Vomit Comet.” If you desire a longer journey, Space Adventures will take you on a 10-day trip to the International Space Station (ISS) for US $25 million, and they even offer flights to the moon. SPACEX is a private company that is nearing completion of its human space transporter, one that NASA will probably use once the Space Shuttle program is grounded. Other private companies developing transporters include Armadillo Aerospace, XCor Lynx, and Blue Origin (owned by Jeff Bezos who is CEO of Amazon). These transporters may also be used for space tourism and for research.

So what happens if we get sick in space? Techniques for conducting physical examinations in microgravity have been studied. These experiments have been done during parabolic flights, space shuttle missions, and longer sojourns at the ISS. During these trips, some gravity is still present because most happen close to earth (micro- or partial gravity environment). For example, in the ISS, gravity is about 88% of that felt at ground level here on earth (astronauts seem to be floating due to the fact that they are traveling at about 17,500 miles per hour). In 1 study, physician-astronauts were asked to evaluate the effects of microgravity on the cardiovascular, musculoskeletal, and neurosensory systems. The evaluation of the latter included only reflexes (which were brisker in space). Head and neck radiologists may be interested in the fact that facial and nasal mucosal swelling are common during space travel (due to fluid redistribution).

The normal flexed position the human body assumes in space may have effects on the spine, and we know that astronauts are taller when they come back from their missions. When arriving back from Mars, it is estimated that bones will have lost nearly 60% of their attenuation (it takes nearly 1 year to recover bone attenuation lost during 1 month in space), so astronauts will be at increased risk for vertebral fractures. Some think that complete bone mass recovery after prolonged space trips is not possible.

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exerts pressure on the bladder floor resulting in the need to urinate, but in zero gravity, overfilling results in urethral compression and urinary retention. This why astronauts urinate on a “preventive schedule” and know how to catheterize themselves.

Teleassistance in medical conditions leads to 2 situations: evacuate or treat on site. Companies providing telemedicine services to remote sites such as Antarctica and Mount Everest have the option to order evacuation, but in space, we will probably have to treat there (though astronauts in low-altitude missions have been deorbited when sick). Transmitted data now routinely include temperature, pulse oxymetry, electronic stethoscope, graphic files, and videoconferencing. Devices using near-infrared spectroscopy that are capable of monitoring a variety of physiologic parameters are being developed. In space exploration, transmit lags need to be kept in mind (40 minutes from Mars to earth, so any real-time interactions are not possible).

Still, we have learned from the experiences of 23 US physicians who have traveled in space that some treatments up there may be possible. Space health monitoring started in 1961 with Yuri Gagarin (and before that with monkeys). Here we need to remember that at the start of the space programs, we did not know the answers to simple questions: Can the heart beat in space? Can we urinate in space? Can we swallow in space? and so forth. As spaceships became bigger, the possibility to diagnose and treat disorders in space became a reality. The US and Russian space programs estimate 1 emergency in space per year and the requirement for advanced life support and/or anesthesia at once every 3–4 years.11 For cardiopulmonary resuscitation, several methods of chest compression have been attempted, but none work well in micro- or partial gravity. Intubation has been studied, but it probably takes too long to be of any good. Surgery has only been tried in animals, and collection of any organic materials released is a (big) problem, though drawing blood is feasible and safe. Overall, space crews receive about 40–60 hours of medical training, and, when combined with telemedicine, the quality of care is comparable to that available in an earthbound ambulance.

Evacuations would require a permanently available vehicle or a second constantly orbiting one. Limited space in these vehicles is not optimal for procedures when evacuating an acutely sick individual. Emergency ballistic re-entries can exceed 7g, and though humans can perform well in hypergravity conditions, devices such as Ambu bags (Ambu, Copenhagen, Denmark) do not. Radio communications are not possible during re-entry. Nevertheless, evacuations from even the moon may be faster than those from Antarctica during winter. In the 1980s, Soviet cosmonauts performed sonography in space, and in 2004, sonography was used to evaluate the shoulders of astronauts in the ISS. Shoulder evaluation may be needed after strenuous extravehicular activities when astronauts complain of pain. Astronauts received a 5-hour course 4 months before launch and completed a 1-hour enhancement program once on-board the ISS.12 Examinations took only about 15 minutes, and, when combined with teleguidance, were thought be good enough for decision-making. Sonography in space has also been used to evaluate the heart and the intervertebral disks.13 Sonography may not be adequate for evaluation of the central nervous system, though it could potentially diagnose abnormal flow in major arteries and then, with focused applications, could be used to enhance fragmenting of clots in patients with stroke.14

A NASA project deals with the stability of medications in space.15 Radiation may alter chemical stability and diminish potency and shelf life, something particularly true of vitamins and amino acids that are essential to maintain a healthy diet on long trips. These experiments may lead to alternate manufacturing, storage, and dispensing methods.

Ideally, larger spaceships could carry CT or even MR imaging scanners. Several teams of investigators are developing CT units that use electron beams guided by magnets and thus have no moving parts. These units could potentially become small enough to be deployed to combat zones and later into space. Optical coherence tomography is being tested in catheters and endoscopes and theoretically could be applied to sonography, CT, and MR imaging. Hand-held MR imaging units may one day be possible as superconducting quantum interference devices improve. A German laboratory has developed a palm-sized magnet capable of 0.7T.16 A hand-held sonography device that looks almost exactly like an apparatus Dr McCoy used in the Star Trek series is available.17

In reality, I think that there will be very little, if any, use for neuroimaging in space. If images are generated, we certainly can interpret them down here on earth. That’s what I like to think of as the ultimate moonlighting . . . or perhaps “Marslighting.”

References

M. Castillo
Editor-in-Chief

http://dx.doi.org/10.3174/ajnr.A2795