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**SPACE MEDICINE - A REVIEW**

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**ABSTRACT**

Space medicine deals with the field of research involved with the adaptation of humans to the unique environment of space. It supports survival, function in this challenging and lethal environment. The day will come when some human beings will spend all their time in space. It is international, intercultural and interdisciplinary, operating at the boundaries of exploration, science and medicine. Motion sickness, negative nitrogen and calcium balance, anemia and radiation exposure, are medical problems seen in space, issues that already affect medical practice outside aerospace medicine. Space medicine doctors have a great responsibility to space workers and spaceflight participants. Flight surgeons help in developing mitigation strategies to ensure the safety, health and performance of space travelers and which is an extreme and hazardous environment. This includes all phases from selection, training and spaceflight itself to post-flight rehabilitation and long-term health.

**KEYWORDS**

Space medicine, Space flight, Astronauts, Space travel and Extra-vehicular activities.

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**INTRODUCTION**

Space medicine is the practice of medicine on astronauts in outer space. The astronautically hygiene is the application of science and technology to the prevention or control of exposure to the hazards that may cause astronaut ill health. Both these sciences work together to ensure that astronauts work in a safe environment<sup>1</sup>. The main objective is to discover how well and for how long people can survive the extreme conditions in space, and how fastly they can adapt to the Earth's environment after returning from their voyage. The medical consequences such as

possible blindness and bone loss have been associated with human space flight<sup>2</sup>. Space medicine can be defined: "The practice of all aspects of preventative medicine including screening, health care delivery, and maintaining human performance in the extreme environment of space and preserving the long-term health of space travelers<sup>3</sup>.

## **TYPES OF SPACE FLIGHT**

Spaceflight refers to those journeys that take place more than 100 km above sea level. This internationally recognized altitude boundary is known as the Karman line. The Karman line is the altitude above which the atmosphere is insufficiently dense for the aerodynamic control surfaces of conventional aircraft to be effective; beyond that lies in space. Three categories of human spaceflight are suborbital, low Earth orbit (LEO; e.g. the International Space Station) and exploration class missions (e.g. missions to the Moon and Mars).

### **Suborbital spaceflights**

They are short, generally lasting no more than a few hrs of which only a few min are spent experiencing the weightlessness of microgravity. The flights involve exposure to increased acceleration in the vertical (GHz) and horizontal (front-to-back; Gx) planes, which can affect the cardio respiratory systems. The degree of acceleration experienced is typically referenced to the acceleration as a result of gravity near the Earth's surface (g; 9.8m s<sup>2</sup>), for example, 6 GHz is head-to-toe acceleration equal to six times g. Cabin pressures are likely to be equivalent to commercial aircraft cabins.

### **Low Earth orbit**

It implies vehicles in orbit around Earth at an altitude of 200–400 km. This is where almost all of human space exploration has occurred; from Russia's Vostok 1 through to the US Space Shuttle program and today's International Space Station (ISS).

### **Exploration class space flight**

This refers to missions beyond low Earth orbit. These encompass expeditions to the Moon, Mars

and other celestial objects and locations including Lagrange points and near Earth objects such as asteroids. Lagrange points are locations where gravitational forces between two large bodies (e.g. the Sun and Earth or the Moon and Earth), are balanced such that a smaller body, such as a space station, can effectively be 'parked' in space and is maintained in a stationary position relative to the two larger bodies. The remoteness of these missions from Earth and their comparatively long duration distinguishes them from the vast majority of our experience in human space flight to date<sup>4</sup>.

## **EFFECTS OF SPACE TRAVEL**

### **Cardiac rhythms**

Among astronauts, a common effect seen is heart rhythm disturbances. They have been related to cardiovascular disease, but it is not clear whether this was due to has greatly mitigated this risk. Other related heart rhythm problems, such as atria, can develop over time, necessitating periodic screening of crewmembers' heart rhythms. Beyond all these problems such as terrestrial heart risks, some concern exists that prolonged exposure to microgravity may lead to heart rhythm disturbances.

### **Decompression illness in spaceflight**

Astronauts use a space suit in space, essentially a self-contained individual spacecraft, to do spacewalks, or extra-vehicular activities (EVAs). They are generally inflated with 100% oxygen at a total pressure that is less than a third of normal atmospheric pressure. They completely remove inert atmospheric components such as nitrogen which allows the astronaut to breathe comfortably, and have the mobility to use their hands, arms, and legs to complete their required work, which would result in a higher pressure suit. After the astronaut dons the spacesuit, air is replaced by 100% oxygen in a process called a "nitrogen purge".

Reduce the risk of decompression sickness, the astronaut must at least spend several hours "pre-breathing" at an intermediate nitrogen partial pressure; and in order to let their body tissues outgas nitrogen slowly enough that bubbles are not

formed. When the astronaut return back to the "shirt sleeve" environment of the spacecraft after an EVA, pressure is restored to whatever the operating pressure of that spacecraft may be generally normal atmospheric pressure. Decompression illness in spaceflight consists of decompression sickness (DCS) and other injuries due to uncompensated changes in pressure, or barotraumas<sup>5</sup>.

#### **Barotraumas**

It is the injury to the tissues of air filled spaces in the body as a result of differences in pressure between the body spaces and the ambient atmospheric pressure. Air filled spaces include the middle ears, paranasal sinuses, lungs and gastrointestinal tract. It is predisposed by a pre-existing upper respiratory infection, nasal allergies, recurrent changing pressures, dehydration, and poor equalizing technique.

Positive pressure in the air filled spaces which results from reduced barometric pressure during the depressurization phase of an EVA. This can cause abdominal distension, ear or sinus pain, decreased hearing, and dental or jaw pain. The abdominal distension can be treated with extending the abdomen, gentle massage and encourage passing flatus. The pressure caused by ear and sinus can be relieved with passive release of positive pressure. Pretreatment for susceptible individuals can include such as oral and nasal decongestants, or oral and nasal steroids.

Due to increased barometric pressure during depressurization after an EVA which result in negative pressure in air fill spaces. The common symptoms include ear or sinus pain, decreased hearing, and tooth or jaw pain. Treatment may include active positive pressure equalization of ears and sinuses, oral and nasal decongestants, or oral and nasal steroids, and appropriate pain medication if needed<sup>6</sup>.

#### **Decompression sickness**

It is the injury to the tissues of the body resulting from the presence of nitrogen bubbles in the tissues and blood. It occurs due to a rapid reduction in ambient pressure causing the dissolved nitrogen to come out of solution as gas bubbles within the

body. In space the risk of DCS can be significantly reduced by using a technique to wash out the nitrogen in the body's tissues. This can be achieved by breathing 100% oxygen for a specified period of time before donning the spacesuit, and is continued after a nitrogen purge. DCS may result from inadequate or interrupted pre-oxygenation time, or other factors including the astronaut's level of hydration, physical conditioning, prior injuries and age.

Other risks of DCS include inadequate nitrogen purge in the EMU, a strenuous or excessively prolonged EVA, or a loss of suit pressure. Non-EVA crewmembers may also be at risk for DCS if there is a loss of spacecraft cabin pressure. Symptoms are chest pain, shortness of breath, cough or pain with a deep breath, unusual fatigue, lightheadedness, dizziness, headache, unexplained musculoskeletal pain, tingling or numbness, extremities weakness, or visual abnormalities. Primary treatment principles consist of in-suit repressurization to re-dissolve nitrogen bubbles, 100% oxygen to re-oxygenate tissues, and hydration to improve the circulation to injured tissues<sup>7</sup>.

#### **Decreased immune system functioning**

In space, astronauts have weakened immune system, which means that in addition to increased vulnerability to new exposures, viruses already present in the body, which would normally be suppressed to become active. T-cells do not reproduce properly in space, and the cells that do exist are less able to fight off infection. NASA research is measuring the change in the immune systems of its astronauts as well as performing experiments with T-cells in space<sup>8</sup>.

#### **Increased infection risk**

A Space Shuttle experiment was carried out in 2006, found that *Salmonella typhimurium*, a bacterium that can cause food poisoning and became more virulent when cultivated in space. NASA stated that, during spaceflight on the International Space Station, microbes seem to adapt to the space environment in ways "not observed on Earth" and in ways that "can lead to increases in

growth and virulence". In 2017, it was reported that bacteria were found to be more resistant to antibiotics and to thrive in the near-weightlessness of space. Microorganisms have been observed to survive in the vacuum of outer space. Researchers reported that after detecting the presence on the International Space Station (ISS) of five *Enterobacter bugandensis* bacterial strains, non pathogenic to humans, that microorganisms on ISS should be carefully monitored to continue assuring a medically healthy environment for astronauts<sup>9</sup>.

### **Effects of fatigue**

It often requires astronaut crews to endure long periods without rest. Studies prove that lack of sleep can cause fatigue that leads to errors while performing critical tasks. Astronauts and ground crews are frequently suffer from the effects of sleep deprivation and circadian rhythm disruption. The problems such as fatigue due to sleep loss, sleep shifting and work overload could cause performance errors that put space flight participants at risk of compromising mission objectives as well as the health and safety of those on board.

### **Loss of balance**

Leaving the space and returning to Earth's gravity causes "space sickness," dizziness, and loss of balance in astronauts. Studies show that how changes can affect balance in the human body involves senses, the brain, the inner ear, and blood pressure. NASA's astronauts use medication such as Midodrine (an "anti-dizzy" pill that temporarily increases blood pressure), and/or promethazine to help carry out the tasks they need to do to return home safely.

### **Loss of bone density**

Spaceflight osteopenia is the bone loss associated with human spaceflight. After 4 month trip into space, it takes about 2–3 years to regain lost bone density. The new techniques are being developed to help astronauts recover faster. Research areas holds the potential to aid the process of growing new bone. Diet and exercise changes may reduce osteoporosis and vibration therapy may stimulate bone growth<sup>10</sup>.

### **Loss of muscle mass**

Due to the loss of muscles in the legs, back, spine, and heart weaken and waste away because they no longer are needed to overcome gravity, just as people lose muscle when they age due to reduced physical activity. Astronauts rely on research areas to build muscle and maintain body mass. They are

- Doing Exercise may build muscle if at least two hours a day is spent doing resistance training routines.
- Hormone supplements (hGH) may be a way to tap into the body's natural growth signals.

### **Loss of eyesight**

After a long space flight missions, astronauts may experience severe eyesight problems. The eyesight problems may be a major concern for future deep space flight missions, including a manned mission to the planet Mars.

### **Orthostatic intolerance**

The astronauts lose fluid volume in space including up to 22% of their blood volume. It result in less blood to pump, the heart will result in atrophy. Heart get weakened which results in low blood pressure and can produce a problem with "orthostatic tolerance," or the body's ability to send enough oxygen to the brain without fainting or becoming dizzy. "Due to the effects of the earth's gravity, blood and other body fluids are pulled towards the lower body. Due to space exploration the gravity get reduced so the blood tends to collect in the upper body instead, resulting in facial edema and other unwelcome side effects. On return to earth, the blood begins to pool in the lower extremities again, resulting in orthostatic hypotension.

### **Radiation effects**

NASA scientists reported that a possible manned mission to Mars may involve a great radiation risk based on the amount of energetic particle radiation detected by the RAD on the Mars Science Laboratory while traveling from the Earth to Mars in 2011–2012.

## **Sleep disorders**

The different methods for combating this phenomenon are constantly under discussion. A partial list of remedies would include:

To sleep at the same time each night, you will (almost) always be tired and ready for sleep.

Melatonin, an anti-aging wonder drug (this was due to the well-documented observation that as people age they gradually produce less and less of the hormone naturally). The amount of melatonin present in the body produces decreases linearly over a lifetime. Melatonin, anti-aging fad was thoroughly debunked following a large number of randomized trials, it was soon in the spotlight once more due to the observation that normal melatonin levels in a healthy person varies widely throughout each day: usually, levels rise in the evening and fall in the morning. Ever since the discovery that melatonin levels are highest at bedtime, melatonin has been purported by some to be an effective sleep-aid – it is especially popular for jet-lag.

The drug ramelteon, a melatonin receptor agonist, is a relatively new drug designed by using the melatonin molecule and the shapes of melatonin receptors as starting points. It binds to the same M1 and M2 receptors in the suprachiasmatic nucleus (the "biological clock" in the brain) as melatonin (M1 and M2 get their names from melatonin). It also may derive some of its properties from its three-times greater elimination half-life.

Barbiturates and Benzodiazepines are both very strong sedatives. It would work (at least short term) in helping astronauts sleep, they have side effects that could affect the astronaut's ability to perform his/her job, especially in "morning." This side effect renders barbiturates and benzodiazepines likely unfit as treatments for space insomnia. Narcotics and most tranquilizers also fall into this category.

Sedative-hypnotics such as zolpidem and zopiclone, better known by their trade names "Ambien" and "Lunesta". These are extremely popular sleep-aids, due in large part to their effectiveness and significantly reduced side-effects. They essentially lack the sorts of side effects that disqualify other insomnia drugs for astronauts, for whom being able

to wake up easily and quickly can be of little importance; astronauts who are not thinking clearly, are groggy, and are disoriented when a sudden emergency wakes them could end up trading their grogginess for the indifference of death in seconds.

Practice good sleep hygiene. The bed is for sleeping only; get out of bed within a few moments of waking up. Avoid by sitting in bed and watching TV or using a laptop. One who spend many hours awake in bed, it can disrupt the body's natural set of daily cycles, called the circadian rhythm. Astronauts have very limited entertainment options in their sleeping areas, another aspect of sleep hygiene is adhering to a specific pre-sleep routine (shower, brush teeth, fold up clothing); observing this sort of routine regularly can significantly improve one's sleep quality.

A drug modafinil that is prescribed for narcolepsy and other disorders is that involve excessive daytime exhaustion. Modafinil has been approved in various military situations and for astronauts thanks to its ability to stave off fatigue. It is not clear whether astronauts sometimes use the drug because they are sleep-deprived, it might only be used on spacewalks and in other high-risk situations.

An amphetamine drug dexedrine is used as the gold-standard for fighter pilots flying long and multiple sorties in a row, and therefore may have at some point been available if astronauts were in need of a strong stimulant. The studies showed, helicopter pilots that were given two-hundred milligrams of Modafinil every three hours were able to significantly improve their flight-simulator performance<sup>11</sup>.

## **ROLES OF A SPACE MEDICINE DOCTOR**

The roles of a space medicine doctor can be considered in the context of the specialty as a whole and the range of scenarios astronauts and therefore flight surgeons may be involved. It is an 'aerospace medicine sieve' that provides a framework to approach the medical, physiological and protection system considerations for different potential spaceflight scenarios and the multiple interactions

to consider. One of the aspect of space medicine that is particularly different from normal medical practice is the role of the flight test doctor. They are working at the interface of extreme environment medicine, engineering, and flying to help design the human into the system. This may involve system specification and design, underlying research or test and evaluation trials that may be conducted in a range of settings: the exercise laboratory, altitude chambers, man-carrying centrifuges and analogue spaceflight environments or the flight environment itself.

A mission to Mars will have to be significantly more self sufficient than current LEO operations and may require the return of a traditional component of human exploration: the ship or expedition doctor. Indeed, NASA stipulates that a physician should be part of the crew for planetary missions longer than 210 days. Their role would include acute care skills to manage trauma or emergency medical situations but traditionally, more holistically, they are also an important moral and social component of the exploration team leadership<sup>12</sup>.

## **MEDICINE IN FLIGHT**

### **Ultrasound and space**

The main diagnostic imaging tool is ultrasound used on ISS for the foreseeable future missions. The radiation emitted from X-rays and CT scans is unacceptable in the space environment. Though MRI uses magnetic to create images, it is too large at present to consider as a viable option. Sound waves from ultrasound create images and comes in laptop size packages, provides imaging of a wide variety of tissues and organs. Ultrasound is currently being used to look at the eyeball and the optic nerve to help determine the cause of changes that NASA has noted mostly in long duration astronauts. The limit use of ultrasound which causes musculoskeletal problems as these are some of the most common and most likely problems to occur.

The challenges for using ultrasounds on space missions is training the astronaut to use the equipment (ultrasound technicians spend years in

training and developing the skills necessary to be "good" at their job) as well as interpreting the images that are captured. The interpretation of ultrasound is done real-time but it is impractical to train astronauts to actually read/interpret ultrasounds. The data is currently being sent back to mission control and forwarded to medical personnel to read and interpret. In future exploration class missions will need to be autonomous due to transmission times taking too long for urgent/emergent medical conditions. The ability to be autonomous, or to use other equipment such as MRIs, is currently being researched.

### **Space Shuttle era**

The additional lifting capability presented by the Space Shuttle program, NASA designers were able to create a more comprehensive medical readiness kit. The two separate packages of SOMS are: the Medications and Bandage Kit (MBK) and the Emergency Medical Kit (EMK). The MBK contained capsule medications (tablets, capsules, and suppositories), bandage materials, and topical medication, the EMK had medications to be administered by injection, items for performing minor surgeries, diagnostic/therapeutic items, and a microbiological test kit.

## **SPACECRAFT EMERGENCIES**

In addition to normal medical considerations, spacecraft emergency scenarios should also be considered. The top three emergencies on board the International Space station are: i) loss of pressurization ii) fire, and iii) toxic leak (e.g. ammonia) all of which have occurred during real missions in the history of human space flight. Loss of pressure could be because of a small or large leak in the habitat, vehicle or spacesuit, each with differing potential causes and emergency responses. The medical consequences of decompression depend upon the rate and magnitude of pressure loss. Hazards include barotraumas, arterial gas embolism, acute hypoxia, decompression sickness and ebullism (vaporization of water in the soft tissues and low pressure areas of the circulation). Astronauts are drilled for these scenarios, donning

emergency oxygen systems to protect from hypoxia or filtering respirators for smoke or toxic fumes. Ultimately they may need to evacuate the spacecraft if the issue cannot be isolated and stabilized. These efforts are locally controlled on the spacecraft but with additional support from ground stations<sup>13</sup>.

### MEDICAL EVACUATION

From LEO, an emergency return is achievable in a matter of hrs although options may be limited by the type and availability of the evacuation vehicle, the physical state of the patient and the on-going medical support required. The ISS emergency return vehicle is the Soyuz; a very reliable and capable launch and return vehicle, but one not designed for evacuation of patients requiring on-going medical support. Furthermore, little is known about the impact on an ill or injured person of microgravity or  $g_x$  acceleration, as occurs during re-entry to Earth's atmosphere. A primate model of hypovolaemic hemorrhagic shock found re-entry may be potentially survivable without volume resuscitation but that appropriate treatment and monitoring would likely optimize clinical outcome. For missions on the Moon evacuation times would be in the order of days and for missions to Mars it would be in the order of months, if it were possible at all. Missions of this type therefore demand a greater level of provision and self-sufficiency, which in turn would be reflected in the equipment, on board pharmacopoeia and medical skills mix of the crew. Education is important to manage the expectations of astronauts or commercial space participants with regard to the medical risks of flight and limitations of the treatment options<sup>14</sup>.

### CONCLUSION

This review indicates there is much that remains unknown in the field of space medicine. It is made clear that the same exploration that takes us out into the endless frontier of space will demand that we also continue to look within and explore the limits of the human body in this the most austere of all extreme environments.

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### CONFLICT OF INTEREST

We declare that we have no conflict of interest.

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