The Mars Doctor: Medical Affairs Reaching Deep Space

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ABSTRACT

This article review the need for the presence of a medical doctor as a critical component for deep space discovery missions. The health of the crew during long space voyages including Lunar settlements would be threaten by numerous factors, mostly related to microgravity, radiation and confinement. The Space Medical Doctor (SMD) would reach a new definition in deep space exploration and the Moon to Mars Initiative. The use of the physician skills and roles are discussed. The SMD on board would provide immediate access to health care and an efficient management of resources, medications, testing, prevention, ground support specialty consults and monitoring of health issues related to the crew. Direct observation, auscultation, listening to the crew member symptoms in an eye to eye conversation and the direct patient examination are irreplaceable skills so needed for an effective therapeutic management. Death and dying during the mission is reviewed. This event might cause psychological, ethical and work crisis for the surviving crew difficult to overcome. Medical risks of infections due to body decomposition, fear of death, and fear of failure may lead to undesirable results. The article discusses procedures to follow. The appearance of new diseases on previously healthy individuals are not only possible but likely. A new academic curriculum for training of the future SMD is proposed. It is concurred that the estimated ratio is one doctor per every 4 crew members or one doctor and one paramedic for every 8 crew members.

Key words: Mars, doctor, space medicine, dying astronaut

I) THE DOCTOR ON BOARD

The preparations to achieve the first manned mission to Mars are divided into two major categories: the machines and the humans. Someone can argue that a human-machine dialectic pair could represent a third well differentiated category, at least in philosophical terms, but the reality is that the human factor is the one attached to every machine or any machine utility creation. This clear conceptualization put the earth inhabitants in a better perspective as the center of the mission. Going to the red planet, landing, exploring and returning to Earth would mark a new step in evolution. The approach to the Moon as a testing ground for future Mars settlement makes it an ideal laboratory for psychosocial, biological and ethical questions that are linked to making our specie a two planets inhabitant.

The health of the mission crew would be threaten by numerous factors, mostly related to microgravity, radiation and confinement. Technology has proven to be sufficient already to make it, to land and to explore the Martian latitudes. Survival is still a question and will remain like that for many years to come. The millions of miles in deep space, the potential communication interruptions or delay, limited testing capabilities, medications and procedural capacity challenges the existence of a healthy crew. Dying during the mission might cause a psychological, work and ethical crisis for the surviving crew difficult to overcome. Medical risks of infection due to a body decomposition, fear of death and failure, may lead to undesirable results. The appearance of new diseases on previously healthy individuals during trajectory are not only possible but very likely. International Space Station missions have documented numerous medical problems debut while staying in low earth orbit, just few hours or minutes away from earthly soil. As *Gene Kranz* would say "…Space is, basically, a test of survival…" (1) and life must be preserved at all cost.

The presence of a medical doctor is critical for the mission positive balance. Training a crew in medical procedures can be of extraordinary help during medical emergencies, assisting and supporting medical interventions, but it will not be an equal substitute of the presence of an experienced physician. The role of a medic in the mission goes beyond providing medical care. As a member of the crew the physician will have astronaut duties to accomplish as well.

Key functions of the Space Medical Doctor (SMD)

1) Flight Surgeon/Primary Care Physician
2) Dentist
3) Scientist
4) Psychologist
5) Safety Officer
6) Pharmacist
7) Nursing
8) Rehabilitation technician
9) Emergency Medical Technician
10) Laboratory Technician
11) Medical writer and journalist

FLIGHT SURGEON/ PRIMARY CARE PHYSICIAN: Even better, the "Space Medical Doctor" (SMD) would reach a new definition on Mars missions. Early in the history of aviation (1922) the need for a special kind of physician who could understand the physical and psychological problems encountered by flyers was well recognized. These physicians were called flight surgeons.(1) (2) The original flight surgeon would now be in charge of the medical care of a crew to Mars. Essentially a primary care physician attending any medical problem, symptoms and health concerns during the trajectory, landing, settlements and activities developed during Martian missions. The SMD on board would provide the necessary immediate access to health care and an efficient management of resources, medications, testing, follow ups, ground support specialty consults and monitoring of health issues from the crew. It would be also the best asset on board for the ground supporting medical division. The direct observation, auscultation, listening to the crew member symptoms in an eye to eye conversation, the human body palpation, and direct patient examination are irreplaceable skills so needed for prevention and effective therapeutic management. The management of a new onset chest pain, for instance, can be of significant importance. A quickly examined crew member could be diagnosed with a muscle pain, shingles or angina pectoris. This could save time, resources expending, avoid crew anxiety or simply could save a life. Training on propaedeutic and semiology must be extensive and clinical experience is a must (a "good clinical eye") due to the limitations in communication, laboratory analysis and radiological exams during the first stages of Mars human exploration. A good analogy, as Dr. Robert Zubrin says, would be a "a country doctor" referring to the skilled and innovative physicians operating in rural areas.(3) The role of alternative medicine would be extraordinary due to the limited availability of medications and the proven efficacy of traditional methods like acupuncture, massage, yoga and meditation.

Emergency surgery, minimally interventional procedures, catheterizations, deep vein access, eyelid eversion or intubation are not meant to be taught and executed safely by telemedicine. The risk involved, even when these are performed by seasoned professionals are to be considered. The support of the rest of the crew assisting during urgent interventions is critical and they must receive training in advance. Once in Mars, the role of the flight surgeon will expand to treat and prevent radiation exposure, injuries originated from work hazards like the wind velocity, and medical conditions resulting from exposure to Mars dust, gas contents and substances like perchlorate, formaldehyde, and hexavalent chromium.(4) Mars gravitational field, will originate a new physiological adaptation period. It is still to determine the continuous progress or regression of medical conditions like vestibular disorders, osteoporosis, muscle atrophy, visual impairments and cardiac remodeling among other to be monitor after the arrival.

DENTIST: Actually a medical doctor with training in dentistry. The probability of dental problems in an exploration mission (beyond the Earth orbit) is real. After one year without a dental examination and a professional cleaning some problems may surface. Tooth decay, gum disease, avulsions, pulp exposure, dental crown detachment, fractures or subluxation may cause significant distress. Toothache and dental abscess are common incidences. The SMD needs to have the capacity to act as the dentist on board and be skilled with the procedures necessary to treat and prevent these health issues.

SCIENTIST: SMD is a mix of a healer and a scientist. The place for scientists in the mission is unquestionable. During the longest trip conducted by humans a multiplicity of protocols designed prior to the mission will take place. Based on the knowledge and set of skills accumulated on the medical career the SMD could be ideal to carry several type of experiments. During the journey to Mars a physician could document the appearance of new diseases, the occurrence or improvement of symptoms related to health degradation, evidence of physiological adaptation, and noticing the cure (or new cures) from previously known space related problems. The SMD could create experiments and therapeutic assays based on observations made during the mission, as well as documenting the crew health evaluation results and statistical information. During Mars (or Deimos and Phobos moons) exploration and possible settlements the physicians could generate valuable field data and continue the search for extraterrestrial life. First hand identification of radiation and geological hazards and environmental toxicity are in order. Chemical interaction of the Martian soil and airborne dust with the astronauts and their equipment needs a detailed investigation. (4) Scientific findings and papers generated during the mission could be transmitted and published even before the crew return to Earth, however, a continuous bidirectional feedback between the ground personnel and the SMD scientist will provide more accurate results. It would be feasible the physician scientist participation on important medical meetings, global medical congresses and even direct academic interaction to discuss preliminary results using modern communication tools.

PSYCHOLOGIST: One of the most important roles of the SMD is participating in the implementation of psychological countermeasures. The mental challenge faced while traveling through deep space during approximately two years can negatively impact the mission. According to data obtained from lunar and low orbital missions (5) (6) (7) (8) (9) the stressors during the journey to Mars could be defined as:

- Microgravity
- Confinement
- Diseases
- Society depravation
- Significant other separation
- Personal relations
- Radiation
- Limited rations
- Noise
- Limited privacy

Even though each factor is being addressed for the most appropriate vehicle design and enhanced astronauts training the stressors will remain. Countermeasures will need a guide, an evaluator and continuous monitoring. SMD may use or enhance the use of:

a) Relaxation techniques
b) Physical exercises
c) Group therapy and coaching

d) Support therapy
e) Ergo therapy
f) Biofeedback
g) Light therapy
h) The use of games, reading, imagery like virtual reality, movies and pictures.
i) Internet and direct family communications
j) The use of private space for meditation, rest and emotional balancing.

Around the clock interaction with ground mental health specialists is key for mission success. The selection process of the crew, the cohesion, interactions during the training phase and the psychological conflicts resolution in an early stage must be addressed carefully.

SAFETY OFFICER: Occupational hazards are a significant concern. Identifying and managing risks during space exploration is critical. Fire, radiation, toxic fumes, biohazard risks, injury prevention, spills, ventilation systems, air pollution, water and food quality, residuals and waste management, all are functions to be part of the scope of work of the SMD. Once in Mars the natural environment and exploration activities would increase risks for accidents, radiation exposure, cross contamination and air pollution by Mars dust and gas contents.

PHARMACIST: Dispensing medications, keeping inventory, quality control, compounding and monitoring potential side effects, pharmacological interactions and dosing are part of the duties of the SMD.

NURSING: Immediate tasks involved the procedures traditionally executed by nurses providing patient care in hospitals and clinics: giving medications, injections, venipuncture, intravenous fluids and medication administration, electrocardiogram, sample collection and wound care. Many overlapping with traditional doctor's duties.

REHABILITATION TECHNICIAN: SMD will be assisting on rehab activities as part of the recovery from injuries. Massage, stretching, passive motion of the joints, combined exercises, adjusting load, frequency and types of activities will be part of the support system provided during the recovery phase. The use of the exoskeleton should be expanded to rescue operations in Mars soil, as a rehabilitation devise, and assisting devise.(10)

EMERGENCY MEDICAL TECHNICIAN (EMT): Operational capabilities of an EMT are quintessential for emergency rescue procedures in space and Mars exploration. The additional presence of a trained EMT or an advanced trained crew member are required to managed complicated cases (11). Immobilization, casting, Intravenous and deep vein access, endotracheal intubation, nasogastric tube insertion and bladder catheterization, thoracentesis, hep-locks, arterial blood gases, astronaut transfer and use of stretchers, all are procedures to be mastered by the SMD. The full support and training from the rest of the crews is necessary. Wound care, eye care, seizure management, cardiac resuscitation and airways assessment and ventilation, are invaluable skills necessary for the SMD.

LABORATORY TECHNICIAN: Not limited to human specimen collection and analysis, but working with robotics during Mars Extra Vehicular Activities (EVA) for specimen selection and preliminary in the field examination. SMD should participate in the processing and monitoring of specimens analyzed on different protocols run during the mission. Adjustments, calibrations and equipment repairs should be assigned also to the SMD.

WRITER AND MEDICAL JOURNALISM: Documentation of preliminary findings and scientific data, crew members health progress, medical procedures log, and press reports must occupy the functions of the SMD. The preparation of scientific and lay press papers would be highly demanded for both the scientific community and the general population. Speaking on international forums from deep space will not be a rare, but a frequent occurrence during the longest human trip.

II) DYING IN SPACE

The worse scenario of a mission would be the end of the life of one crew member. The second worse might be the experience of being part of the surviving crew. The appearance of a new disease acute and fatal should not surprise any medical personnel involved in supporting deep space exploration. Pulmonary embolism, acute myocardial infarction, stroke, fatal arrhythmias, and sepsis could happen with real probabilities. Heart aberrant conduction pathways, genetically rare coronary arteries, and coagulation abnormalities could remain undetected by clinical or laboratory testing prior to the expedition. The appropriate training, immediate decisions, skilled clinical interventions, monitoring and therapeutics applied might not be still enough to save an astronaut life. Death and dying in space is expected to cause a significant disruption in the crew dynamic with logical anguish, fear, guilty feelings, remorse, and resentment. These can negatively impact the mission success and failure to address this issue may be associated with additional problems.

Astronauts must be trained in how to deal with death and dying during space missions. Procedures for a burial ceremony, human body disposal, mourning treatment and coping mechanisms should be planned ahead. Spaceships designers must consider this unfortunate eventuality and elaborate on the technology needed to deal with it. If the SMD is one of the survivors the crew could benefit from a direct professional intervention during this crisis. The event could be so sudden and unexpected in many ways (Sudden Death Syndrome) than even the SMD would need therapy as part of the affected crew. The main focus must be to reestablish the wellbeing of the crew and pushing forward to continue for the successful completion of the mission.

Disposing the body remains: Since it is unknown the forensic signs and the human post-mortem changes in microgravity conditions (fluids excretion, bacterial growth rate and body decomposition process) planning for this contingency is quintessential.

GOING (months and weeks before landing) Keeping a human body after death inside the space vehicle might bring additional pain and suffering to the crew. There is no morgue and there is very limited physical space available. The human body decomposition and contamination of the spaceship could follow shortly after. Closed air systems are not designed for such eventuality. Sealing the body in a space suit within one hour seems to be the most appropriate next step. Delaying this procedure may lead to the effects of rigor mortis or cadaveric spasms which could create additional challenges. The body must be respectfully embalmed restraining the arms and legs to keep anatomical position. Helmet, gloves and boots must be locked in the same manner of the preparation done for an EVA. The spacesuit could be depressurized. These will delay the natural decomposition and fluid exudation process. After a brief burial ceremony the next procedure will be a burial at space. Following old traditional mariners burials at sea the human remains could be taken to the outer space using an EVA airlock vacuum chamber. This procedure should be assisted by other astronaut in prevention of possible malfunctions.

LANDING (within hours to land, during or after landing) The vicinity of the planetary landing, procedures and preparations may contribute to postpone the burial. If time allows embalming the deceased in its own spacesuit, helmet, gloves and boots should followed the unfortunate loss. Once landed on the celestial body the crew must proceed to the burial ceremony. It could be as decorous as laying the astronaut remains in a naturally depressed terrain (small hole or pond shaped area) and cover it with stones and planetary sand. The place must be marked with religious symbols significant for the deceased and the national flag indicating the presence of human remains, name and date. Cold temperatures, dry environment, the vacuum of space and intense radiation might all help to delay significantly the decomposition process. It must be taken into consideration the effects of the spaceship takeoff over the tomb (flames, fumes, vibration and wind velocity). Water sources, if any, must be identified before the final selection of the place to leave the body to rest.

RETURNING: Coming back to Earth from a deep space mission might be very stressful. It represents the end of a long journey where the crew has been exposed to high radiation, limited rations, low exercise level, immunosuppression, muscle atrophy, osteoporosis, and other effects of prolonged space exposure. The crew is also two years older and new medical problems may appear. In case of expiration within weeks or month before earth reentry the crew may procedure according to measures proposed above in the GOING section. Within hours of the reentry it should be followed the same general guidance proposed on the above LANDING section.

The terrible events presented in this part of the paper are considered unfortunate and rare, although a really possible scenario. The crew anticipation and preparation for this eventuality must be carefully designed to avoid unnecessary fears and insecurity. Ground support and protocols on the other hand must be elaborated and thoroughly tested long before launching. Psychological support from the ground personnel must contemplate dealing with prolonged grieving. It must include mourning and bereavement coping technique uses, the management of antidepressants, and the importance of family support. The focus from this point should remain on survival. The rest of the crew should realize once again the importance of a successful mission completion. The value of ergo therapy at this difficult stage can not be emphasized enough as a method to focus on one task at a time. The value of the hands-on activities is in paying attention to the job to do which take away the attention from suffering. It is important to help the crew understand that every activity will help them to come back safely to earth and in that way to honor the departed hero. The role of the SMD could be crucial in these circumstances providing direct support, relief and therapeutic interventions.

III) ACADEMIC TRAINING

Current residency program curriculum in traditional specialties like Space Medicine, Family Medicine, Internal Medicine, Surgery and Orthopedics do not contemplate all aspects necessary to provide efficient medical services during deep space exploration. A preparation of physicians that one day may serve as a crew SMD should include the diagnosis and management of diseases and injuries affecting many organs and systems. In addition the future health officer on board should know evacuation procedures, safety regulations, and research protocols.

CORE CURRICULAR ROTATIONS FOR SPACE MEDICINE DOCTORATE TRAINING:

1) Family Medicine Module

   a) Primary Care/Internal Medicine 6 months

   b) Surgery 3 months

   c) Orthopedics 2 months

   d) Urology one month

   e) Ophthalmology and ENT one month

   f) Psychiatry and Psychology one month

   g) Dental Therapist/Pharmacy compounding three months

2) Anesthesia a) General, b) Regional, c) Local, d) Pain management. 2 months

3) Nursing procedures and Laboratory 2 months

4) Academic research and Alternative Medicine one month

5) Emergency Medical Technician procedures one month

6) Emergency Medicine and Intensive Care 2 months

7) Rehab Medicine including cardiovascular physiology and cardiac rehab. One month

8) Radiology with emphasis in the use of ultrasonography 2 months

9) Aerospace Medicine Module (4 months)

   A) Flight Surgeon Introduction (six weeks)

   B) Aerospace Medicine (Practical rotations six weeks)

   C) Safety Officer and Telemedicine (one month)

10) Elective rotations (one month every year) Consider Wilderness Medicine.

Total: 36 months for an Space Medicine Doctor formation with deep space exploration and interplanetary orientation. This could be structured a fellowship offered to Aerospace Medicine, Family and Internal Medicine specialists. Overlapping of contents is important to improve the learning curve.(12) (13) (14) (15)

All the skills must be added to the general astronaut training and to the specific mission tasks. The training should be directed to acquire specific set of skills for procedures to be performed during prolonged space missions and emergencies (16) (17). The academic program must include all the potential candidates and must keep the non selected physicians as on the ground support team. A group of professionals who think alike on the ground do not prevent the use of experts. The advantage is the level of synchronicity and the similarity in points of view from trainees with similar background. Academic training and practical experience would be required for the treatment of dental emergencies and its prevention. In flight dental emergencies have been a rare event given current data and records. Long duration space missions raise the probability of in-flight dental emergency similar to the preflight rates. A dental therapist level must be the minimum academic level to be acquired in training.

CONCLUSIONS

1) At least one medical doctor should be present in every mission to deep space and during the total length of any lunar settlement (Moon to Mars Initiative).
2) The role of a physician should not be limited to medical interventions but should involve prevention, research, safety and manufacturing. The SMD should be one more active crew member with astronaut responsibilities.
3) The healthy ratio should be one doctor for every crew of 4 astronauts or one doctor and one paramedic for every crew of 8.
4) The role of the SMD in the mission might become critical for the crew survival and a successful mission completion.
5) Dying in space is not inly possible but probable. Preparations for this scenario must be made and technology development should consider dealing with the end of life.
6) A new curriculum must consider the challenges of deep space exploration and particularly the availability of limited resources. Alternative medicine, anesthesia, psychology, pharmacy, nursing, laboratory, and radiology should be an integral part of the physician curriculum.
7) A multicenter academic training must be considered including training in different countries for the acquisition of the best skills in any particular field

In addition to all of the previously said one must keep in mind the frequency of symptoms that anybody can experience in a two years period. Add the stressors of space conditions and the need of a doctor will arise. Nothing substitute the presence of a physician who can talk face to face. The more crew members the higher the number of incidences and the higher the probability of multiple simultaneous health threat incidents. The most important medical resource of the mission is the *medic* on board.

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