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MARTIAN EMERGENCY MEDICAL CRISIS MANAGEMENT

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INTRODUCTION

Accidents and injuries happen. Frequently.

Despite superior training and caution, despite careful preparation, injuries and accidents occur which have significant impact upon our lives. In the everyday world, when an accident happens, people are taken to the emergency department for treatment, usually by an ambulance with trained emergency responders. This combination of emergency medical technicians, paramedics, emergency medicine physicians and trauma surgeons provide highly skilled medical care to victims of accidents and injuries.

Distance and time separate people in space from prompt medical care. When the first manned crew goes to Mars they will be the most isolated people in history. Prompt emergency medical care from outside sources will be impossible to obtain. The crew will have to be self-sufficient and provide for their medical care.

MEDICAL EMERGENCIES

NASA and other sources estimates that in a prolonged mission such as the projected Mars missions there will be almost certainly an injury, severe enough to require a visit to an emergency department if it had occurred on Earth.[1] Therefore the question should not be "How do we manage a medical emergency IF it occurs on a Mars mission," but "How do we manage a medical emergency WHEN it occurs on a Mars mission?" There are several different methods and models to choose.

Should the problem be handled from Earth by telemedicine, or should the crew manage the crisis, with later assistance from Earth.[2] Should a physician be a member of the crew, or could the crew be trained adequately in emergency medical treatment and use checklists.

The technique most often cited is the use of telemedicine to provide expert medical care in space.[3] This is the method of choice for the International Space Station and Earth orbit operations.[4] This allows specialists on Earth to examine and direct medical care to a remote location, while allowing the participants on site to have a lower level of training.[5] The

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technology is rapidly expanding in this field, including remote sensing, haptic force feedback technology, and telepresent surgical techniques.[6] The primary limitation is time delay for transmissions between the subject and operator. This becomes a major factor on a Mars mission as the round trip transmission time from Mars to the Earth and back is about forty minutes. There is a two month period where transmission between Earth and Mars is not possible when they are on opposite sides of the Sun, but this could be avoided by placing a satellite relay system to bounce signals around the Sun.[7]

For the majority of medical tasks, such as routine health surveillance, data collection, and minor medical care, this time delay is acceptable. The time delay will only be a factor in an acute medical emergency. Emergency medical problems must be handled in a prompt manner. Emergency Medicine and Trauma Surgery recognize that there is a "Golden Hour" in which treatment and patient stabilization must be performed to ensure patient survival. Delaying emergent medical treatment past an hour will often prove fatal. This time limit requires a high degree of autonomy by the astronaut crew. They must be self sufficient to the extreme, and must have a high degree of training.

WHY SEND A PHYSICIAN?

Should a physician be sent on the Mars crew? Why should a physician be sent, taking a spot that would otherwise go to a geologist or other scientist? The answer is yes, a physician should be sent on the Mars Crew. The reason is simply that the cost of not having a highly trained individual available to treat acute illness and injury is simply too high. The loss of the function of a crewmember would severely affect the crew's ability to complete their mission functions, and could affect the survival of the entire crew.

It is possible to invent multiple scenarios where the entire crew is injured or killed. Some opponents to having a crewmember as a physician cite this as a reason to not have a physician on board. "If anything happens" it is said, "the entire crew will perish, why bother wasting a crew spot on a physician if they will not be able to help?" This is a fallacy. It is more likely that an injury will occur to an individual. Accidents that happen to the entire crew may occur, put this does not mean that there should not be a physician to treat and minimize injuries on the crew.

The loss of a single crewmember would mean the loss of research and exploration time and capabilities. Loss of the pilot could complicate or prevent safe return of the entire crew. A severely injured crewmember would require that the other members of the crew spend additional time from their schedules in direct medical care of that crewman, thus removing a second or even a third crewmember form a large portion of their daily activities. This would have a major negative impact upon mission capabilities. The public relations fallout from a preventable death would be enormous, and could hurt further missions.

CROSS TRAINING

Physicians often have varied scientific backgrounds prior to their training in medical school. In the United States physicians must have completed an undergraduate degree prior to matriculation to medical school. Many physicians have backgrounds in rigorous scientific fields such as chemistry, physics, biology and engineering. Degrees in these fields are required to be competitive for admission to medical school. It would be simpler to take a physician with such a background and provide them with the necessary training to be a field scientist then it would be to take a field scientist and make them a physician.

It takes a minimum of seven years to become a general physician, and training in surgical specialties may take up to twelve years. By choosing a physician who has an undergraduate degree in science, field training will be shortened to an acceptable level in preparation for a Mars exploration mission. This means that the doctor on board will not be an extraneous "Ship's Doctor" waiting around for an emergency to happen, but will instead be a productive, fully functioning member of the crew.

TYPES OF EMERGENCIES

There are three basic types of accidents with injuries:

1. Those that will kill you no matter what you do
2. Those that will get better no matter what you do
3. Those that will get better only with prompt treatment

In any given situation the type of injury is essentially random. For serious injuries, some will kill the person immediately, some will not be life threatening, but will require treatment, and some will go either way. The third set is where emergency training can have the greatest benefit, but emergency training can also reduce the severity of injury and shorten recovery time in the second set as well. Therefore in the majority of injuries the presence of a physician will make a significant difference in the acute management of the patient, and can make a life or death difference.

The actual types of injuries that could be expected on a manned mission to Mars include a litany too long to be explored in detail in this paper. They include traumatic injuries such as falls, blunt trauma, fires, electrical injuries, decompression injuries and injuries from equipment failure. Psychological factors and inattention can contribute to errors and accidents.[8] There are unknown environmental injuries, such as the effects of accidental exposure to the Martian atmosphere. This could result in hypothermia, toxic side effects, and pulmonary damage from particulate inhalation, and hypobaric injuries. There are numerous dangerous toxins and explosive items carried onboard the spacecraft.[9] There are inherent medical problems involved with long-term spaceflight and microgravity that have detrimental consequences such as calcium bone loss, autonomic instability, and muscle atrophy[10] which could increase the risk of accidents and increase the severity.[11] Prolonged microgravity may increase the risk of dangerous cardiac arrhythmias[12] and kidney stones.[13] There are risks from infectious disease organisms on board the spacecraft[14] and the dangers of the crews weakening immune system. There are numerous difficulties inherent in predicting what type of accidents will occur, because if you could predict them then you would be able to prevent them.[15] Therefore the best response is to be prepared for the worst possible event that can happen. By taking care of the downside, the upside will take care of itself.

WHO SHOULD GO?

Because medical care that is not time dependant can be taken care of from Earth, a physician chosen for a Mars mission should be from a field that deals with emergencies. Two types of physicians primarily deal with emergencies. The first are Trauma Surgeons, who specialize in the care of patients with blunt and penetrating traumatic injuries. The second are Emergency Medicine Physicians are a type of physician who work in the emergency department, and are experienced in handling all types of emergencies, including toxic exposures, medical and cardiac emergencies, trauma, and environmental injuries.

The Emergency Medicine specialist may provide more of an advantage on the expedition. The emergency medicine physician specializes in resuscitation and management of all types of emergencies. The emergency physician works in a chaotic and unpredictable environment in the emergency department. Trauma surgeons focus on the surgical management of blunt and penetrating injuries. This is a more focused approach then the generalist approach of the emergency physician. The emergency physician may be better equipped to treat injuries that do not require emergent surgery.

Patients who have injuries severe enough to require emergent surgery have a much higher morbidity and mortality rate. Even with proper treatment and intervention there is a high risk of death. In the final risk benefit analysis it may seem that if the patient is sick enough to need a trauma surgeon their survivability is so low it may not be worth having the physician on board. For the severely injured but not immediately fatal patient, an emergency physician trained in a broader range of emergencies would seem to be a more appropriate choice to provide "more bang for the buck."

PHYSICIAN VS. CREW MEDICAL OFFICER

The next question often asked is "Why take a physician when you can train a pilot/geologist/chemist/engineer to provide medical care?"[16] The best answer is that specialists do better then non-specialists.

Prompt recognition and treatment of emergency conditions allows for improved treatment. Operational experience in handling emergencies provides a background that would be difficult to obtain during the heavy training schedule required for a Mars crew.

To demonstrate the possible impact of varying levels of training to an emergency situation an experiment was performed using the human patient simulator.

EMERGENCY MEDICAL CRISIS MANAGEMENT

The design of the experiment was to compare the performance of three levels of care providers. To simulate the response of individuals trained at various levels, and their response to emergency medical crises a series of simulations was performed.

Three groups were utilized. The first group consisted of Emergency Medicine Attendings. These individuals have completed all specialty training and are Board Certified by the national specialty boards. This is the highest level of medical training available. The second group consisted of Paramedics and Emergency Medical technicians. These are individuals who daily handle the initial care of all types of emergency problems. The final group consisted of third year medical students. These students have completed two years of classroom training, and are involved in the clinical aspect of their medical training, which is an additional two years.

Three standardized emergencies deemed likely to occur during a manned mission to Mars were created and implemented using the Eagle patient simulator. This is a complex, sophisticated mannequin that very accurately represents human response to injury. All encounters were videotaped and graded on a standardized system such as is used for Advanced Trauma Life Support Training and Emergency Medicine oral examinations.

The three scenarios chosen involved a single astronaut and three crew responders. The crew was informed that they could ask "Mission Control" for any information or suggestions, but all responses would be delayed by 20 minutes. The crew received a short 5-minute briefing of the scenario and then was sent to the room containing the simulator.

The first scenario involved a trauma scenario in which the astronaut develops a pneumothorax and internal bleeding leading to shock. (See appendix for further information) The second scenario involved a rapid decompression with embolism, hypothermia and neurologic deficit. The third scenario was an exposure to hydrazine resulting in respiratory distress, stridor and hypoxia.

All settings, key actions, and results were determined prior to crew testing. The results were tallied based on analysis of the videotape. Scoring was based on completion of critical actions and time to complete the scenario. Delay due to contacting mission control for guidance was noted.

RESULTS

As expected the attending physicians performed at a significantly superior level. All critical actions were rapidly performed, there were no adverse events, and mission control was not contacted prior to disposition.

The paramedics and EMT's performed at an intermediate level. All critical actions were performed, but not as efficiently as for the attending physicians. Time to diagnosis and treatment was about 33% longer than that of the attending physicians. Mission control was contacted for guidance once. There were no adverse events.

The medical students were significantly poorer in performance. Their time to diagnosis was up to 75% longer than that of the attending physicians. Mission control was contacted in each case, and this was responsible for the majority of the delay. There was a death due to unrecognized esophageal intubation with the endotracheal tube, and failure to oxygenate in the third scenario.

CONCLUSION

Crews on a mission to Mars will encounter emergency medical crisis situations. In order to handle these situations efficiently and provide the greatest margin of safety for the crew, physicians trained in Emergency Medicine and Trauma Surgery should be incorporated into the crew. The higher level of training provided by these physicians and the skills they possess would be difficult for non-physicians to obtain. These skills can be crucial in determining the difference between life and death for an injured crewmember. Therefore it is imperative that an attending level physician who is appropriately trained be included in a manned mission to Mars.

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APPENDIX MARTIAN EMERGENCY MEDICAL CRISIS MANAGEMENT

SIMULATOR SCENARIOS

- Anesthesia and monitoring equipment removed from simulation center
- placed on floor with body perpendicular to tilt-pan-zoom camera
- patient cables placed along side wall
- space suit on simulator, work boots, helmet off to the side(if available)
- speaker to patient relocated to skull flap
- IV access available

PROPS:

- storage shelves in area stacked with empty, closed boxes
- Thomas Pack (located in back, far wall under control room window) includes:
    - Airway equipment(scope/blades/ETT/mask/NC/OA/NA)
    - IV setup
    - stethoscope
    - LR
    - Oxygen tank placed on side, against wall with app. Valve
    - Ambu bag
    - Pulse oximeter machine
    - $ETCO_2$ detector
    - Silver rewarming blankets
    - Drugs:
        - Albuterol
        - Aminophylline
        - Corticosteroids
        - (5) of each: epinephrine, atropine, lidocaine, morphine
    - LifePak 12
        - LifePak 12 simulator attached; remote in control room

PATIENT PROFILE

Age:	35 years old
Gender:	Male
PMH:	None
PSH:	Appendectomy 20 years ago without complications. Cholecystectomy 2 years ago without complications.
MEDS:	None
Allergies:	None

OPERATOR NOTES

Decompression Scenario
(Hypothermia, Air Embolism +/- Pneumothorax, Neuro deficit)

Site: Mars Hab Module

Situation: Four astronauts have been on the Mars Hab Module for the last six months. (This allows time for the body to equilibrate to gravity changes) An astronaut develops a leak in his space suit and quickly returns to the air lock. During the re-pressurization process he looses consciousness and drops to the floor. When the other astronauts arrive, they find their colleague in and out of consciousness. Initial VS are BP in the 90's, HR about 110. Patient quickly decompensated over the next 5 minutes. VS changes are BP in 70-80's, HR 130-150 and SaO_2 falls to 80-90's.

Role: First responder astronaut (Captain) [participant placed on wireless microphone and remote headset with microphone located on top of head and out of contact]

Objectives:

1. Identify signs and symptoms of hypothermia.
2. Identify signs and symptoms of air embolism.
3. Identify signs and symptoms of pneumothorax.
4. Perform appropriate medical interventions for the above conditions:
    - Airway management
    - IV access
    - Rhythm recognition
    - Vital signs assessment
    - Pharmacological intervention
    - rewarming
    - neuro exam
    - recognize need for re-pressurization

HAB MODULE	SIMULATOR
	Default Patient: *death spiral ACTIVATED *Monitors: Sao_2,art line, *EVENTS: *Nasahypothermia *Nasaembolism *Nasapneumothorax (on standby, us *only if* patient needs to deteriorate further) VS – BP 90's, HR 110's, SaO_2 95+ EKG - normal
First responder (astronaut) hears his colleague call out for help. Arrives to find colleague on floor with helmet removed and space suit partially removed from victim.	Event-Trigger Nasahypothermia Allow time for responder to assess VS. Voice: Patient in and out of consciousness. VS: BP drops to 80's, HR 140-150's, SaO_2 drops to 80's
First responder should respond by: -Assess VS -Start IV -Apply O_2 via mask or NC -Rewarm patient -Administer appropriate pharmacologic therapy	Simulator response: After **1.5 min** of first event triggered, ACTIVATE Nasaembolism event. MANUAL CONTROL: *EYE *Change pupils to sluggish and 75 Dilated. Patient becomes confused. Doesn't know where he is etc. -Watch VS, use ADVANCED CONTROLS to keep VS at set limit -Start IV at 125 cc/hr -Apply O_2 via mask -Administer drugs at appropriate dosages
If appropriate measures are implemented, patient should slightly improve and then stabilize.	Deactivate all events and allow patient to improve.
If appropriate medical interventions are not performed, patient decompensates and dies.	Allow patient to decompensate and die. ACTIVATE Nasapneumothorax event.
	END OF SCENARIO

Toxic Exposure to Hydrazine
(Asthma/Pulmonary Edema with stridor, Hypoxia)

Site: Mars Hab Module

Situation: Four astronauts have been on the Mars Hab Module for the last six months. (This allows time for the body to equilibrate to gravity changes) An astronaut is coming in through the airlock and performs inadequate decontamination procedures after removing his space suit. He immediately begins to experience SOB. He calls on the intercom system to notify his colleagues that he is in distress. When the other astronauts arrive, they find their colleague on the floor experiencing difficulty in breathing. Initial VS are BP in the 120's, HR about 110. Patient quickly decompensated over the next 5 minutes. VS changes are BP in 100's, HR 120-130 and SaO_2 falls to 70-80's.

Objectives:

5. Identify signs and symptoms of hydrazine exposure.
6. Identify signs and symptoms of pulmonary edema.
7. Identify signs and symptoms of hypoxia.
8. Perform appropriate medical interventions for the above conditions:
    - Begin decontamination procedures
    - Airway management
    - IV access
    - Rhythm recognition
    - Vital signs assessment
    - Pharmacological intervention

HAB MODULE	SIMULATOR
	Default Patient: *death spiral ACTIVATED *Monitors: Sao_2,art line, *Nasahydrazineexposure(Bronchospasm folder) *Nasahydrazinepulmonary(Pulmonary edema folder) VS – BP 90's, HR 110's, SaO_2 90's EKG - normal
First responder (astronaut) arrives after being summoned by the victim. Arrives to find colleague on floor having difficulty breathing. Calls for help from other team members.	Event-Trigger Nasahydrazineexposure Allow time for responder to assess VS. Voice: Patient experiencing difficulty breathing. VS: BP drops to 80-90's, HR 110-120's, SaO_2 drops to 80-90's
First responder (team) should respond by: -Assess VS -Start IV -Apply O_2 via mask or NC -Administer appropriate pharmacologic therapy *Lasix *Atropine *Mannitol *Albuterol (inhaler) *Steroids *Aminophylline	Simulator response: After **1-2 min** of first event triggered, ACTIVATE Nasahydrazinepulmonary event. (TERMINATE this event after 2 minutes or beginning of therapy) Patient begins to wheeze and presents with stridor. -Watch VS, use ADVANCED CONTROLS to keep VS at set limit. AC settings: **Perf.Resis (PR). - - 0.2* **HR - 8* Once Nasahydrazinepulmonary event DEACTIVATED then set AC to: **PR - –0.6* **HR - 8* -Start IV at 125 cc/hr -Apply O_2 via mask -Administer drugs at appropriate dosages
If appropriate measures are implemented, patient should slightly improve and then stabilize.	Deactivate all events and allow patient to improve.
If appropriate medical interventions are not performed, patient decompensates and dies.	Allow patient to decompensate and die. ACTIVATE Nasapneumothorax event.
	END OF SCENARIO

Multi-Trauma Scenario
(Hypovolemia/shock, Pneumothorax, Pelvic Fracture and Concussion)

Site: Mars Hab Module

Situation: Four astronauts have been on the Mars Hab Module for the last six months. (This allows time for the body to equilibrate to gravity changes) An astronaut is in the storage area and attempting to remove boxes from the top of the shelves. As the astronaut is removing a large box, he suddenly falls and knocks several heavy boxes down on top of him. Other astronauts hear the loud crash and come rushing into the storage area. When the other astronauts arrive, they find their colleague awake but in severe pain. Initial VS are BP in the 90's, HR about 110. Patient quickly decompensates over the next 5 minutes. VS changes are BP in 60 – 70's, HR 130-140 and SaO_2 falls to 70's.

Objectives:

9. Identify signs and symptoms of hypovolemia / shock.
10. Identify signs and symptoms of pneumothorax.
11. Identify signs and symptoms of pelvic fracture.
12. Perform appropriate medical interventions for the above conditions:
    - Airway management
    - IV access
    - Stabilization of pelvis
    - Rhythm recognition
    - Vital signs assessment
    - Pharmacological intervention
    - Pain management
    - Evaluation of blood loss for possible transfusion

MARS HAB MODULE	SIMULATOR
	Default Patient: *death spiral ACTIVATED *Monitors: SaO_2,art line, *EVENTS: *Nasahypotension *Nasapneumo VS – BP 90's, HR 110's, SaO_2 95+ EKG - normal
First responder (astronaut) hears loud crash and screaming in storage area. Arrives to find colleague on floor with boxes around and on top of victim. Calls for help from other team members.	Event-Trigger Nasahypotension –(*2 minutes before scenario participants enter room)* Allow time for responder to assess VS. Event – ACTIVATE Nasapneumo – *(1 minute after participants enter room)* Voice: Patient in sever pain, alert VS: BP drops to 60-70's, HR 130-140's SaO_2 drops to 70's
First responder should respond by: -Assess VS -Start IV -Apply O_2 via mask or NC -Needle decompression -Administer pain medication	Simulator response: -Watch VS, use ADVANCED CONTROLS to keep VS at set limit -Start IV at 125 cc/hr -Apply O_2 via mask -do needle decompression -give morphine at appropriate doses
If appropriate measures are implemented, patient should slightly improve and then stabilize.	Deactivate all events and allow patient to improve.
If appropriate medical interventions are not performed, patient decompensates and dies.	Allow patient to decompensate and die.
	END OF SCENARIO

REFERENCES

[1] "Human Exploration of Mars: The Reference Mission of the NASA Mars Exploration Study Team", NASA SP-6017, Stephen J. Hoffman and David I. Kaplan, editors, Lyndon B. Johnson Space Center, Houston, Texas, July 1997.
[2] Holland D. Some virtual reality and telemedicine applications useful for long duration spaceflight from a systems engineering perspective. Stud Health Technol Inform. 1999; 62: 141-7.
[3] Dorn CR. Applications of telemedicine in the United States space program. Telemed J. 1998 Spring; 4(1): 19-30.
[4] Grigoriev AI. Medical monitoring in long-term space missions. Adv Space Biol Med. 1997; 6: 167-91.
[5] Crump WJ. An application of telemedicine technology for otorhinolaryngology diagnosis. Laryngoscope. 1996 May; 106(5 Pt 1): 595-8.
[6] Campbell MR. Surgical care in space. Tex Med. 1998 Feb; 94(2): 69-74.
[7] Davis JR. Medical issues for a mission to Mars. Tex Med. 1998 Feb; 94(2): 47-55.
[8] Manzey D. Mental performance in extreme environments: results from a performance monitoring study during a 438-day spaceflight. Ergonomics. 1998 Apr; 41(4): 537-59.
[9] James JT. Carcinogens in spacecraft air. Radiat Res. 1997 Nov; 148(5 Suppl): S11-6.
[10] Vernikos J. Human physiology in space. Bioessays. 1996 Dec; 18(12): 1029-37.
[11] Buckley JC Jr. Preparing for Mars: the physiologic and medical challenges. Eur J Med Res. 9-Sep-1999; 4(9): 353-6
[12] Rossum AC. Evaluation of cardiac rhythm disturbances during extravehicular activity. Am J Cardiol. 1997 Apr 15; 79(8): 1153-5
[13] Whitson PA. Renal stone risk assessment during Space Shuttle flights. J Urol. 1997 Dec; 158(6) 2305-10.
[14] Viktorov AN. Residential colonization of orbital complex "Mir" environment by penicillium chrysogenum and problem of ecological safety in long-term space flight (abstract). Aviakosm Ekolog Med. 1998; 32(5): 57-62.
[15] Billica RD. Perception of the medical risk of spaceflight. Avait Space Environ Med. 1996 May; 67(5): 467-73.
[16] Gonzalez MA. An integrated logistics support system for training crew medical officers in advanced cardiac life support management. Comput Methods Programs Biomed. 1999 May; 59(2): 115-29.