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Healthcare Beyond Earth

A DISCUSSION OF HEALTHCARE IN SPACE
IN THE CONTEXT OF SOCIAL AND POLITICAL FACTORS
INTERACTING WITH THE FUTURE OF MARS COLONIZATION

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Introduction

The starry sky has gotten closer in the past half-century, when humanity went from taking our first step on the Moon in 1969 to launching Voyager 1 towards interstellar space.[2,3] This expanding frontier has propelled many organizations to plan a manned spaceflight to Mars.[4]

Meanwhile, space medicine has been developing in the background. Today NASA is analyzing the data from the Twins Space Study[5], devised with the help of the Kelly identical twin astronaut brothers. To research the effects of space on the human body, Scott Kelly spent almost a year in space while his brother remained on Earth.

Space exploration, frequently thought of as the domain of engineers and astrophysicists, indeed intersects with the field of medicine. The crossover of these two seemingly unrelated worlds will soon clash in a more evident and influential way, considering the revived, evolving landscape of human space travel with prospects of putting a human being on Mars.[4] However, these ambitions are somewhat dimmed by plans to cease funding for the International Space Station (ISS)[6], whose operations allow for unique research and technology development as well as inspire international collaboration.[7,8]

In light of new technologies and initiatives to reach beyond Earth atmosphere, public and private entities have established their own space programs[4,9], culminating in an emerging space race with serious consequences that can jeopardize the safety of astronauts and the future of spaceflight if timelines are rushed and a regulatory framework is not set. To be prepared, we need to ensure the safety of astronauts and potentially off-Earth colonizers.

In this essay, I will discuss various elements that healthcare in space should address and sociopolitical aspects of such endeavours across space and on a potential Martian colony.

Health Hazards

To illustrate the challenges that spaceflights and the colonization of Mars entail, it is useful to first discuss the health hazards that humans will experience, as safety is primordial to the success of missions.

Gravity changes dramatically during a 3-year return-trip to Mars (2 years of travel time and 1 year of activity).[10] Our bodies have evolved to function with Earth gravity[11]; therefore, in space the body undergoes changes outside of normal physiological conditions. Fluid redistribution occurs and edematous tissues of the eye can result in visual changes.[11,12] The microgravity also leads to significant muscular disuse atrophy and bone density loss.[10-14] Even the vigorous exercise regimens to which astronauts adhere are insufficient to fully prevent those musculoskeletal losses.[12,14] The losses could prove to hinder any plans on the Martian surface as astronauts would need to adjust to the new gravity.[10,11,14]

Without Earth's atmosphere and magnetic field, the relatively thin walls of a spacecraft or habitat can only partially block space radiation.[11-13] Ionizing cosmic rays can induce genetic damage, thus increasing the risk of cancer, mutations, immune weaknesses, and nervous system damage.[10,12] The latter manifests as changes in cognition, motricity, behavior, and degenerative tissue diseases.[11-13] If these can be observed on ISS missions lasting months, a round-trip to Mars or a permanent habitat make it even more likely for such pathologies to arise. They can be difficult to manage with current technology and treatments, and they can negatively impact daily tasks, teamwork, and mental faculties.[12]

The closed environment of a space station can favour infection transmission, especially when accounting for immune systems weakened by microgravity and space radiation.[10-12] Moreover, discomfort in the living and working areas caused by temperature, noise, and lighting can disturb mood, sleep, and behaviour.[12]

Another factor inducing a "decline in mood, cognition, morale, or interpersonal interaction"[12] is the confinement in such a long mission. Sleep disorders and mental health issues like depression have been observed. On one hand, overwhelming workloads lead to fatigue and stress.[11-13] On the other, monotony, often seen on return-trips when the mission is complete and the excitement of reaching a destination has faded, has resulted in boredom and mental fatigue.[12] These factor into the risks of conflict between individuals retained in a sealed complex.

As such, it is understandable that astronauts additionally experience isolation, being so distant from home, Earth. Communication would also become strenuous the closer they get to the Red Planet. Since signals can only travel so fast, it can take more than 40 minutes to send a message and receive a response.[12] This makes conversations impossible and would require different communication strategies, a challenge both technological and social considering how heavily we rely on verbal communication.

Additionally, the distance makes emergency resupplies and mission aborts impractical. Indeed, if the crew expends their resources or encounters equipment failures, then they would have to improvise with whatever is at their disposition. As for mission aborts, on the ISS, the last resort is to evacuate and return to Earth[12,13], but in the case of a spaceflight between Earth and Mars, this becomes heroically difficult to manage due to distance, delayed communication with headquarters, and finite resources.

Sustaining an Extended Spaceflight and a Martian Habitat

There are other wider-scope aspects that can be derived from these health hazards and non-biological aspects that are crucial in maintaining a healthy, cohesive community on Mars.

Raw resources

Food and shelter are basic needs that need to be satisfied wherever a person is. This becomes particularly arduous in a place where resources are far from being readily exploited and processed.

To ensure proper nutrition of more than a handful of astronauts for an extended length of time, techniques to generate food will become critical.[12] Horticulture will need to be further developed. Ideally, fresh food can be grown in Martian facilities as well as on spaceships compatible with Earth and Martian resources to bring less weight into space by having return-trips resupplied with local materials; to form a more robust contingency plan; and to provide space travelers with variety.

As for the actual habitats in which humans can reside, it would be inefficient and costly to send astronauts to serve as construction workers. Instead, a fleet of robots can, autonomously and with additional control by Earthbound coordinators, build the habitat.[15] Others have suggested sending machinery that can 3D-print and use in situ resources as construction materials.[16,17]

Efficient utilization of resources will be important in streamlining operations, avoiding unnecessary waste, and reducing costs. The stages at which this optimization can focus are at extraction, usage, and recycling or repurposing of used materials.

Medical resources

Medical care for astronauts and future colonizers is two-sided: providers and facilities.

Candidate selection for missions and colonization will require that each team include at least one physician. Diagnostic and surgical skills will be valued as well as experience with medical problems probable during spaceflight or their stay on Mars. Once selected these medical experts should receive pre-Mars space medical training. Psychotherapists or psychiatrists should be strongly considered considering the isolation and mental health issues that crewmembers can experience.[11-13]

As for facilities, they should be capable of supporting interventions in response to the most probable and dangerous medical problems. One manner to do so is to establish a medical center with capabilities comparable to a tertiary healthcare center's emergency department stripped to its appropriate essentials.

For a permanent colony on Mars, there will be a strong interest to research and incrementally advance technology to creatively solve novel problems encountered during prolonged spaceflights and colonization. Tools and materials should be robust and reliable with a long lifetime before failure. Crewmembers should be trained to repair or even modify them if necessary. Materials or packaging that provides radiation shielding is key, especially for valuable devices and medications.[12] To further bolster effective medical independence of the colony, medical techniques and establishment of new baseline normal values, in the context that Mars possesses one third of Earth's gravity, become helpful for diagnostics, treatment, and follow-up.[11,12]

Furthermore, colony growth poses quite the problem. Would it be better to procreate on Mars; transport embryos ready to be implanted in a surrogate woman or somehow grown in vitro in a Martian laboratory; or even to solely rely on interplanetary transportation of humans to seed colonies? Procreation can be quite risky considering gestation already carries its own risks in addition to the unknown effects of radiation on embryogenesis. Embryo importation also has similar risks; and in vitro growth, though currently being experimented on Earth but not entirely impossible in the future, would require even more lab space and equipment, which may not be the best cost-efficient strategy but at least no woman would be risking their health from a pregnancy on Mars with limited resources. As for the last option, from an engineering standpoint, transportation of working adults or even children translates into increased masses and costs of material to be launched into space.[16]

Management

Whether a colony should be dependent on an Earth-based headquarters brings another discussion – that of governance. Management of routine tasks and crises requires leadership, cohesion within the team or established community, and a system of governance and proper communication.

For the government of a small-scale operation to Mars, it would be logical to follow protocols like those of previous manned missions. However, for a larger, permanent colony, an international Earth-based organization can become the governing board, which can promote international collaboration on many fronts and receive multilateral funding and resources. In contrast, it also becomes conceivable to have a governing body on site. Depending on the size of the community, a direct democracy can be feasible as SpaceX CEO Elon Musk suggests or a representative democracy with the added component of a supportive or supervising institution on Earth.[18] Regardless of which type of government is chosen, the priority should always be the health and wellbeing of the colonizers as individuals and as a group.

An agreed upon framework would account for human life and the unexpected. For example, each person going to Mars should consent to being kept healthy and live up to the capacity of given resources without risking the rest of the group's survival. A utilitarian ethics allows flexibility in strategy and may be crucial when difficulties arise or when emotions incite rash actions with insufficient concern for others and the future of the Mars program.

Funding & Politics

Public support and views on the usefulness of space exploration are linked to the funding for these programs. How we fund and view research into the health and safety of our astronauts can have a long-lasting impact on healthcare on Earth and beyond.[19]

Devices designed by or derived from research done at NASA has already yielded a multitude of medical technologies that are still in use today. For example, a red light-emitting diode used to grow plants on space shuttle experiments has been adapted into a "hand-held, high-intensity, LED unit… intended for the temporary relief of minor muscle and joint pain, arthritis, stiffness, and muscle spasms, [while] also promot[ing] muscle relaxation and increases local blood circulation".[20]

One of the observed driving forces supporting this expansion of the human species to an interplanetary one has been the fear of death and human extinction.[19] Consequently, this may push for a rush for space colonization with unreasonable risks to health and safety, lack of efficient resources and policies. Any mission failures at the very beginning of this next step in spaceflight may deter future programs.

Moreover, there has been a generational rush for Mars, a cohort of people who felt like they have "waited long enough" since the race to conquer space in the 1960's and 1970's.[19] At the time, it was a contest to the moon between the USA and Soviet Russia. Now many more space agencies from various countries are involved, some of which have cooperated on occasion, e.g. the ISS. Space agencies from the USA, Europe, Russia, and China as well as the private space industry have the potential to collaborate on large-scale costly programs – or to compete against one another.[19,21] Organizations affiliated with governmental bodies require public funding that is critical to their operations, and national sentiments about the importance of space exploration will affect said financial support.

Multilateral participation encompasses not only funding but also materials, human resources, and data sharing. Indeed, these agencies can use their weight as governmental bodies to negotiate lower costs of materials and manufacturing and share these high-grade resources. The most skilled candidates and scientists can collaborate to share research, technology, and improve the chances of mission success and productivity. Just as these partnerships can bring countries closer, they can also cause friction due to prior political tensions, reluctance to share classified information, operational or administrative differences, or divergent opinions at any step of the way. Decision-making becomes more complex as disagreements will have to be resolved more cautiously and with more parties. On the upside, a successful international cooperation has practical purposes for space missions; stable politics and inclusivity will help establish a fertile ground for the history of a peaceful, cohesive Mars colony and beyond.

Lessons & Comparisons Drawn from the Past

If each country or agency independently attempts to reach Mars, this may cause the European colonization of the Americas to repeat itself. Conflict between the countries arriving on Mars with their own citizens would most likely occur and lead to tensions regarding resources, technology, territory. Lessons can be learned from our violent past. When the Europeans explored and colonized the Americas en masse in the 16th to 18th centuries, it was a race for territorial control; and mercantilist policies led to the empowerment of and warfare between the empires.[22,23] For the colonization of Mars, many parallels can be drawn as well as nuances: immigration into a new, harsh environment; involvement of many governmental bodies; and the search for a new life.

Sailing in a spacecraft across the tumultuous ocean of space to arrive at the destination alive is already a feat, but survival in this distant land would have just begun. Like the settlers that followed Jacques Cartier, astronauts who venture to the Red Planet will know relatively little about the foreign, bitter environment that awaits them. Radiation experienced on Mars and dust storms with gusts of 94 km/h can be thought of as the space age's equivalent of wild predators and freezing storms of Canada.[10-13,24] Furthermore, many dangers and few resources stand between liftoff and colonization. Although recent observations of the geochemical composition of the Martian surface has revealed an interesting minerology, these are not particularly useful in their small quantities and state of matter.[25] Therefore, the Martian surface is rather barren, and in the absence of an indigenous population, no extrinsic guidance can be procured to help adapt to this new environment, as opposed to the European immigration to America and their encounters with the natives who have lived there for millennia.[26]

Another similarity is the participation of multiple entities of power. Back then, it was European empires and state-sponsored settlements.[22,23] Today the Mars race involves many countries, coalitions, and the private sector. Despite the development of the Global Exploration Strategy's non-binding forum of the Framework for Collaboration[27], this level of international collaboration is not necessarily at the forefront of these programs and this lack of close partnership increases the risk of tension and conflicting agendas. Some seek gains such as personal or national glory, marketization of spaceflight. These all foster competition and potentially military control of space, just as it did during the Cold War's Moon race between Soviet Russia and the United States or the European conquest by colonization of the Americas.[28]

While some may strive for scientific and technological advancement for military dominance over other nations or economic profits, human curiosity and sense of discovery also drive these innovations. Much of the research and technological developments for space programs have been directly involved or adapted for biomedical use on Earth, as mentioned earlier.[20] Another psychosocial reason for this expansion is the fear of human extinction and a perceived need for our species to become interplanetary, especially in the context of climate change and continuing population growth.[19]

The next point of comparison is the experience of the colonizers themselves. While Europeans of the 16th and 17th centuries traveled for a new life, whether it was out of hope for a wealthier one, autonomy, or an escape from the post-Middle Age setting of Europe at the time[22], potential settlers of Mars may also want to flee from the tragedies or their own struggles on Earth.[29] Furthermore, Martian leadership may conform with the regulations set by Earth-based authorities; or in the far future when a level of self-sustainability is somehow acquired, they may demand an independence not so dissimilar from the former European colonies of today. The environment, the focus on basic or different needs, the diversity of settlers on Mars may very well lead to the development of a new local culture and worldview. Cultural transformation makes psychological sense at the nexus of environmental change, a need for a sense of belonging, distance from their place of origin, and multiculturalism among the colonizers.[10]

Conclusion

Space medicine and the associated healthcare structure will not be constructed in a vacuum; they are framed by resources and the sociopolitical environment in which we design our space programs.

Using myopic policies such as mercantilism in the service of material wealth and a neo-imperialistic mindset can destabilize the proper functioning of an Earth-based administration by instigating vested interests, undermine the cohesion of the Mars colony, and ultimately risk the lives of those here and there.

Colonizing Mars is admittedly a far more complex undertaking than briefly described in this essay. The next frontier is an opportunity to avoid repeating mistakes of the past and to be better prepared not only for the next step, but for the next hundred. Hopefully, we as a species will have developed sufficient foresight and willingness to expand our horizons of possibility by improving human life on Earth and extending it into the cosmos.

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