The Role of Artificial Intelligence (AI) in Space Healthcare

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Monitoring and maintenance of the overall health of astronauts on the International Space Station (ISS) are carried out by the Crew Health Care System that includes the Environmental Maintenance System, Countermeasures System, and the Health Maintenance System.[5] Such a system is made up of a series of individual components not integrated for redundancy so that any of them can be easily replaced without interfering with other operating parts of the system.[5] Then, ground control oversees and provides remote assistance to astronauts in space throughout the mission. Indeed, although astronauts are highly trained, they might need refreshment or guidance when executing tasks requiring high precision and accuracy, as in the case of medical procedures.

Looking at the needs of future crewed missions,[7] destination, lack of continuous real-time communications, and impracticability of immediate re-entry lead to a re-evaluation of the requirements for onboard medical capabilities. For example, missions beyond low Earth orbit require the crew to be Earth-independent, or autonomous, with respect to medical care (NASA, 2015).[6] Hence, there is an urgency in establishing priorities for the development and optimization of medical systems and supporting technology.[1,6]

To date, emerging technology and advanced algorithms are thought to be parts of a solution. However, there is no certainty that such solutions will meet envisioned requirements and performance within the timeframe left, i.e., 5 yr before the next crewed mission on the Moon in 2024. In this paper, the role of artificial intelligence in space healthcare is discussed to highlight needs and gaps that may slow down the development of systems supporting future crewed missions.

Artificial intelligence (AI) is starting to be applied to medical fields. Radiology, cardiology, and pathology[8] are a few medical fields where intelligent systems are already being used. Here, large datasets are the basis for building the level of intelligence the machine needs for executing tasks with high accuracy and precision. Although much research has been carried out in this field, the integration of AI in healthcare has just begun.[8] Indeed, AI has been shown to reach performance comparable to that of medical doctors in specific tasks only (known as weak AI). Currently, general AI or artificial general intelligence is far from being operational in medicine.

The development of any AI for healthcare in space faces various challenges that distinguish it from AIs developed for terrestrial healthcare. The sections below describe the four aspects of this context.

1. Ethics. In space, ethical principles are part of the decision-making process about whether a risk is acceptable by current health standards and what conditions shall be satisfied for being ethically acceptable in space exploration. Space medical capabilities rest on the ethical framework and on the medical risk model from which risks of long-duration missions are quantified (Antonsen et al.[1]). Currently, the medical risk model refers to the astronaut population only. For sustaining commercial activities of humans in space, the model shall be updated to account for commercial astronauts and space tourists. It implies a re-evaluation of risks and mitigation strategies, in addition to a modification of procedures. Then, medical capabilities supported or produced by commercial activities may be seen as business-driven, in contrast with the corresponding purpose-driven missions of space agencies. Here, the underlying ethics and legal framework shall meet the needs of the space environment and

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shall be compatible with the principles of space exploration (Marsh[4]).

2. Healthcare. AI, applied to space medicine and space medical capability, is general AI. The intelligence needs to be advanced enough to perform the tasks currently executed by ground support (like guidance in procedures), and for overseeing the overall health of astronauts. Indeed, an optimal in-flight intelligent medical system shall: differentiate the changes induced by the variation of the gravitational pull from those promoted by the duration of exposure to outer space; and take account of the medical history, of changes in performance and behavior, among others. Besides the measurement of physical quantities (temperature, oxygen, and others), the integration of intelligent systems into the architecture would allow the use of the habitable volume of the vehicle as a source of medical data or a tool that facilitates medical monitoring and treatment (Cinelli,[2] Viola et al.[9]). Colored lights and contact-free heartbeat measurement are examples of devices with biomedical application that function through the use of surface areas or volumes of free air, where the signal travels from the source to the receiver. Therefore, the optimal general AI shall act as a comprehensive healthcare system with human-like intelligence (see **Table I**).
3. Medical conditions. When setting requirements and priorities in engineering, attention is given to charted medical conditions, especially those seen during/after flights, or between flights or missions. Indeed, in a few cases, the variation of the gravitational pull is thought to be the primary cause of initiating processes leading to medical conditions. Then, the likelihood of in-flight occurrence on a human mission may be considered of secondary importance depending on the context. Although uncharted medical conditions or compounded conditions are of major concern for enabling permanent human presence in outer space, requirements shall build on a real possibility of occurrence of charted conditions only, regardless of their in-flight occurrence.
4. Data. General AI in space healthcare shall build on data collected during each phase of a flight. This includes terrestrial data, in-flight data, data before/between flights or missions, and environmental data. In contrast with the large datasets of terrestrial AIs, astronaut data are a special dataset that presents limitations. Such data: A) belong to a small population with higher physical and mental performance than the general population, B) are representative of charted or compounded processes of acclimation to outer space, and C) may be limited in utilization for the following reasons. Measurements conducted during human studies on the ISS usually involve a small group of astronauts, a fraction of the total astronaut corps. These experiments are carried out to answer open questions in research, not to create large datasets as those needed for building AI. Datasets exist for organizing and classifying medical information and for boosting the understanding of the human body, but such datasets may not be appropriate for building general AIs. For example, weak AIs able to categorize brain images for identifying injuries or pathologies are trained over datasets composed of thousands of images of the same type (Topol[8]). AIs developed solely on space medical data might not reach the needed level of performance if adopting a technical approach similar to that used for terrestrial AIs. Then, as not all medical measurements can be carried out in space (for example, invasive measurements or MRIs), data collected with alternative tools and those collected on the ground are essential for allowing continuity in the understanding of the role of gravity on the human body. While humans can easily discern information received from various sources, such an ability needs to be given to any AI.

Table I. Artificial Intelligence in Terrestrial vs. Space Medicine.

	EARTH	SPACE
Data available to train AI	• Big data	• Released/unclassified • Classified • Underreported
Types of data available	• Terrestrial data	• Terrestrial data • In-flight data • Environmental data • Before/between missions
Data belongs to	• A large population	• Astronauts
End-user will be	• A person (medically trained)	• Formal astronauts • Commercial astronauts • Space tourists
Medical conditions to be managed	• Known	• Charted • Uncharted • Unknown
Healthcare to be provided	• Specific	• Specific • Comprehensive
Capabilities supported	• Business-driven	• Purpose-driven
Ethics applicable	• Local/national ethics	• Space ethics • Medical risk model of a mission
Law applicable	• Local/national law	• Space law

Another challenge may arise from underlying ethics and privacy considerations that skew available data. In-flight medical data can be released by space agencies, or classified, or underreported. Indeed, there is great pressure to keep medical information private or underreported because any disclosed medical information may jeopardize an astronaut's chance to return to space (Institute of Medicine[3]). Hence, the understanding of human body adaptation may face great challenges in data utilization in addition to those related to accuracy, precision, and reproducibility (see Table I).

Additionally, future human spaceflights may include guest commercial astronauts and space tourists, two populations of which little is known. Against this backdrop of limitations, analog human studies (such as bed rest studies) and extreme activities on Earth (such as mountain expeditions) are scenarios for producing data that may resemble observations like those seen in space. In contrast with the current progress in the commercial space sector, more research is needed in space medicine to ensure safety and preserve the health of all travelers in outer space.

In conclusion, this paper discusses the challenges of AI in space healthcare looking broadly and in context. Due to the speed of the current progress in technology, it is essential to highlight the differences known and anticipated in the application of AI applied to space healthcare as compared to terrestrial healthcare. Due to the substantial differences in the underlying ethical and legal frameworks, AI produced for terrestrial applications is not transferable to AI for space medical applications, regardless of the size of datasets. However, terrestrial AI may play a role as a subset of general AI in space healthcare, supporting the understanding of processes of adaptation to the space environment. Weak AIs can be produced for tackling specific physiological processes occurring in space. Still, their accuracy and precision may be strongly impacted by the size of datasets, resulting in being nonrobust. AI in space healthcare must be comprehensive by design, becoming general AI, and its validity will depend on the relationship existing between space agencies and contributing parties for creating and sharing data.

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REFERENCES

1. Antonsen E, Shah R, Reed R, Canga M. Conceptual drivers for an exploration medical system. Paris (France): The International Astronautical Federation; 2016:1–10. [Accessed March 2020.] Available from https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20160010839.pdf.
2. Cinelli I. Artificial intelligence for space medical capabilities: a new frontier. In: XPOMET 360° Next Generation Healthcare. Berlin (Germany): Medizinisch Wissenschaftliche Verlagsgesellschaft; 2019:202–208.
3. Institute of Medicine. Safe passage: astronaut care for exploration missions. Washington (DC): The National Academies Press; 2001.
4. Marsh M. Ethical and medical dilemmas of space tourism. Adv Space Res. 2006; 37(9):1823–1827.
5. NASA. 2011. CHeCS (Crew Health Care Systems): International Space Station (ISS) medical hardware. [Accessed March 2020.] Available from https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20110022379.pdf.
6. NASA. 2015. NASA Space Flight Human-System Standard - Revision A: Crew Health. [Accessed March 2020.] Available from https://standards.nasa.gov/standard/nasa/nasa-std-3001-vol-1.
7. NASA. 2018. The Global Exploration Roadmap: what is new in the Global Exploration Roadmap? [Accessed March 2020.] Available from https://www.globalspaceexploration.org/wordpress/wp-content/isecg/GER_2018_small_mobile.pdf.
8. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. Nat Med. 2019; 25(1):44–56.
9. Viola AU, James LM, Schlangen LJM, Dijk DJ. Blue-enriched white light in the workplace improves self-reported alertness, performance and sleep quality. Scand J Work Environ Health. 2008; 34(4):297–306.