International Space Medicine Clinical Decision Making Working Group

Space medicine clinical decision making: Difficult treatment decisions and palliative care

White Paper

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Declaration of Interest:

Dr. Hamilton and Dr. Caswell have contributed to the development of AI clinical tools and assistants. Dr Caswell is the founder and director of SpacePort Australia Pty Ltd. Dr Andrew W Kirkpatrick has consulted for Zoll Medical, 3M, and Innovative Trauma Care Corporations, and is the principal investigator for the COOL trial: Closed or Open after Laparotomy for Source Control Laparotomy in Severe Complicated Intra-Abdominal Sepsis (https://clinicaltrials.gov/ct2/show/NCT03163095). Dr. Biernacki is a contractor for a Rocket Doctor, a Telehealth AI company based in Canada

Executive Summary

- The extraterrestrial environment is characterized by its overwhelming hostility towards human life forms.
- The human physiological response to altered gravity environments impairs healing, therapeutic procedures, the efficacy of medicine, resuscitation efforts, and recovery processes.
- Exploration Class Space Missions (ECSM) and extraterrestrial colonization deliver operational environments that will present significant challenges to the provision of healthcare and emergency medical services in both traumatic and non-traumatic situations.
- In such environments, autonomous clinical decision-making might become necessary. This is due to various factors, including the inability to facilitate timely medical communications, electrical failures that disrupt telecommunications with Earth stations and centres, and the absence of technology capable of establishing secure links over vast distances.
- Clinical decision-making will be required to balance the needs of the patient, crew longevity, limited resources, and mission priorities.
- Considering varying cultural and religious perspectives, advisable to conduct discussions concerning Do Not Resuscitate (DNR) orders and clinical palliative care decisions within the space operational environment prior to flight.
- Astronauts and other space travelers should comprehend and consent, with full awareness, that treatment options and clinical outcomes may differ from those familiar to them on Earth. Clearly delineated levels of acceptance or refusal of invasive healthcare should be established, with final treatment decisions entrusted to the nominated treating clinician.
- To ensure that clinical decision-making prioritizes patient outcomes and survivability, it is advisable to establish an international convention along with a status akin to the 'Good Samaritan Law'.
- In addition to an established convention, the development of a 'Good Samaritan Law' is recommended, accompanied by a mutually agreed international legal framework, to safeguard clinicians and crews who may be compelled to make difficult treatment and palliative care decisions within operational environments.

- In the envisioned future, mature AI medical assistants may provide clinical advice to an attending physician to aid clinical decision-making in the space environment.
- The scope of capabilities of an AI medical assistant should strike a balance among the treatment needs of a patient, various outcome scenarios, the operational environment, clinical resources, available medication and its efficacy with that environment, as well as overall health and longevity of the remaining crew.
- It is recommended that the member signatories of the Artemis Accords (https://www.nasa.gov/artemis-accords/) initiate discussions to guarantee the inclusion of all cultural and clinical perspectives within operational space medicine guidelines.
- A comprehensive and globally recognized legal framework and convention concerning the ‘Good Samaritan Law’ concept should be integrated into the Artemis Accords to afford cross-cultural protection for clinicians and crews who may be compelled to make challenging treatment and palliative care decisions.

Contents

Introduction

The space environment presents numerous unique challenges to the human body. When a patient is exposed to this environment during injury or disease processes, it may be necessary for the physician to adopt an alternative care model. The moral-ethical treatment framework familiar to most physicians, particularly those practicing in Western countries, emphasizes patient outcomes as indicators of treatment success.[1] Multiple prior reviews of "adverse human physiology in spaceflight" consider the effects of the space environment and physiological de-adaptation, which may influence the results of medical interventions.

The decision to administer or withhold treatment, as well as the selection of resources to use, will be guided by the patient's presenting illnesses and diseases, alongside the requirements to sustain a normal, healthy, or health-optimized physiological state within the space environment. Hazards constitute an inherent aspect of the space environment, with many identified, risk-assessed, and managed; however, uncontrolled hazards and the variability in patient responses to treatments will influence clinical outcomes.

Future space missions will encounter new environments and hazards, with an increased likelihood of reduced Earth-based support and communication capabilities.

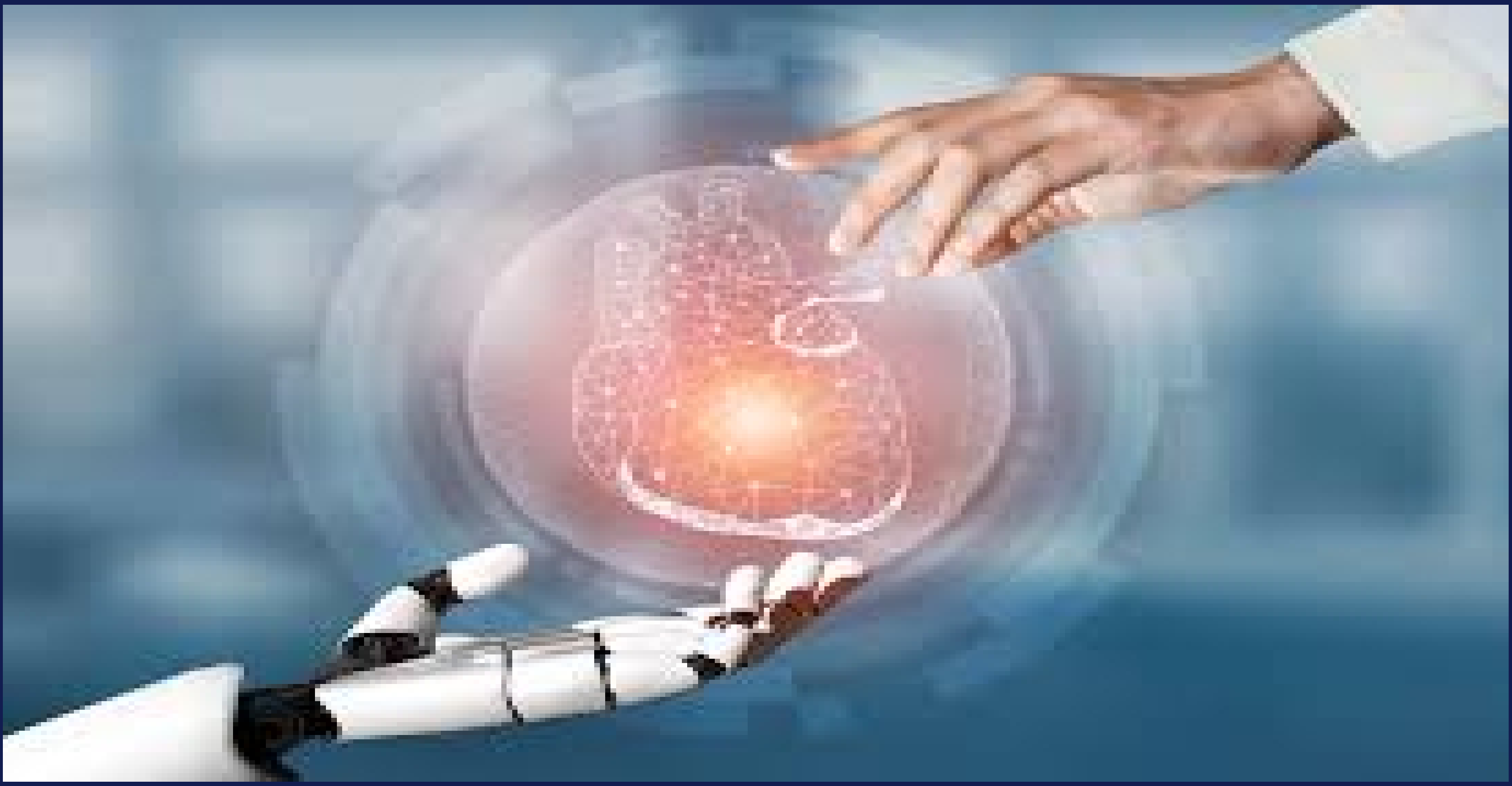
Unidentified complicating factors within this novel environment that may result in diminished clinical and clinician support include: distance from Earth or the nearest advanced medical facility; unreliable communication channels with Earth-based support or sophisticated medical facilities; limited or inaccurately available resources onboard; and yet-to-be-identified hazards. Additionally, there may be ethical dilemmas involving the prioritization of patient, resources, crew, and mission objectives.

Those providing solitary or autonomous medical support may or may not face professional or ethical challenges, and access to resources may be limited or unrestricted.

Uncontrolled hazards may or may not be predictable, and similarly, the health risks associated with unknown and uncontrolled hazards may also be unpredictable. It is anticipated that exploration could result in increased extravehicular activity (EVA) or the development of new requirements for

EVA in uncontrolled environments, potentially leading to spontaneous incidents. Furthermore, concepts such as habitat failure and life support system failure will present their own challenges.

Medical intervention will be determined based on the available treatment options, resources, tools, medications, and the experience and competency of the attending medical provider. The ideal or best practice options for any given illness, condition, or medical incident may not be available. Clinical support and second opinions may not be available.



Conclusions

The scenario of sub-optimal health outcomes, palliative care, or death in operational space environments has not been extensively addressed, particularly within the context of enclosed, complex psychosocial communities such as those found in spacecraft, future space habitats, or colony housing.

Striking a balance between patient welfare, crew health, and mission success may complicate and exacerbate clinical decision-making processes in these operational settings. Furthermore, a patient requiring medical treatment in an environment with limited resources and support will be mentally and physically vulnerable.

Space medicine experts and international space law communities have yet to deliberate on the applicable ‘rules,’ the appropriate ethical and clinical guidelines, and the definition of a safe medico-legal paradigm for future operational space environments.

Cultural Approaches to Health Care, Palliative Care and Dying

Sixty-one countries have signed the Artemis Accords; however, these countries are not uniform in their healthcare systems or expectations. The signatories do not share identical approaches to treatment decisions, emergency care provisions, or palliative care and end-of-life options. It is inevitable that crews and working consortia will comprise individuals from various countries, each with distinct cultures and religious beliefs.

It should be noted that some personnel may demonstrate greater acceptance of medical hardships, suboptimal health conditions, and healthcare systems. Conversely, others may have experienced medical care augmented by nearly unlimited resources and advanced technologies. These disparities underscore not only the physical aspects of medical care delivery but also the challenges related to belief, acceptance and the perceived futility of medical interventions.[3-6]

Differing cultural perspectives can result in intrapersonal crew conflicts, especially during emotionally intense situations such as emergencies and disasters. Individuals tend to form their expectations based on their known and lived experiences, which are influenced by their culture and community. Consequently, these factors shape their perceptions of acceptable health outcomes.[7]

Pre-flight training should emphasize and familiarize crew members with cultural and religious attitudes, as well as approaches to illness, sub-optimal outcomes, and death.[8] The training should adopt a general framework initially; however, it should be customized more specifically once the crew composition is known, to foster a harmonious respect for each individual's culture.

This training should not supersede the operational imperative outlined in Recommendation 1.

Identified Communication Issues

Communication issues refer to two themes: a) communication with the patient, their family, and next of kin, who may or may not be part of the mission crew; and b) communication with medical support or advice services.[9-10]

With the prospect of an increasing number of individuals employed in space and traveling there for recreation or habitation, the issue of solo medical decision-making warrants discussion. Additionally, for individual clinicians and crew members, it requires appropriate training.

Clinical decision-making is frequently conducted within a team environment, following discussions and reaching consensus, with input from both healthcare professionals and Next of Kin (NoK) or family members. Patients are involved in this process when they are able to contribute to the discussion. The foundation of this framework is 'informed consent,' which can be granted only if the individual providing consent—be it the patient or their representative—possesses the capacity to understand and logically process the information.

The consent must be given voluntarily and without coercion. Anticipation of communication, as described, is most effectively managed prior to its necessity, i.e., incorporated into astronaut training, with similar discussions and reviews involving NoK, family, and friends of the astronaut, crew, or payload specialist. Refer to Recommendations 1 and 2 for a scheme designed to fulfill this educational objective.

Direct communications from Earth to the International Space Station (ISS), situated in Low Earth Orbit (LEO), constitute a relatively stable aspect of space operations. The effectiveness of communication reach and clarity was demonstrated during the recent Artemis II mission, which orbited the Moon and returned safely to Earth on April 11, 2026.

It is anticipated that communication with extraterrestrial settlements or Exploration Class Space Missions (ECSM) will not consistently exhibit the same level of clarity or stability.

Approaches to Palliative Care

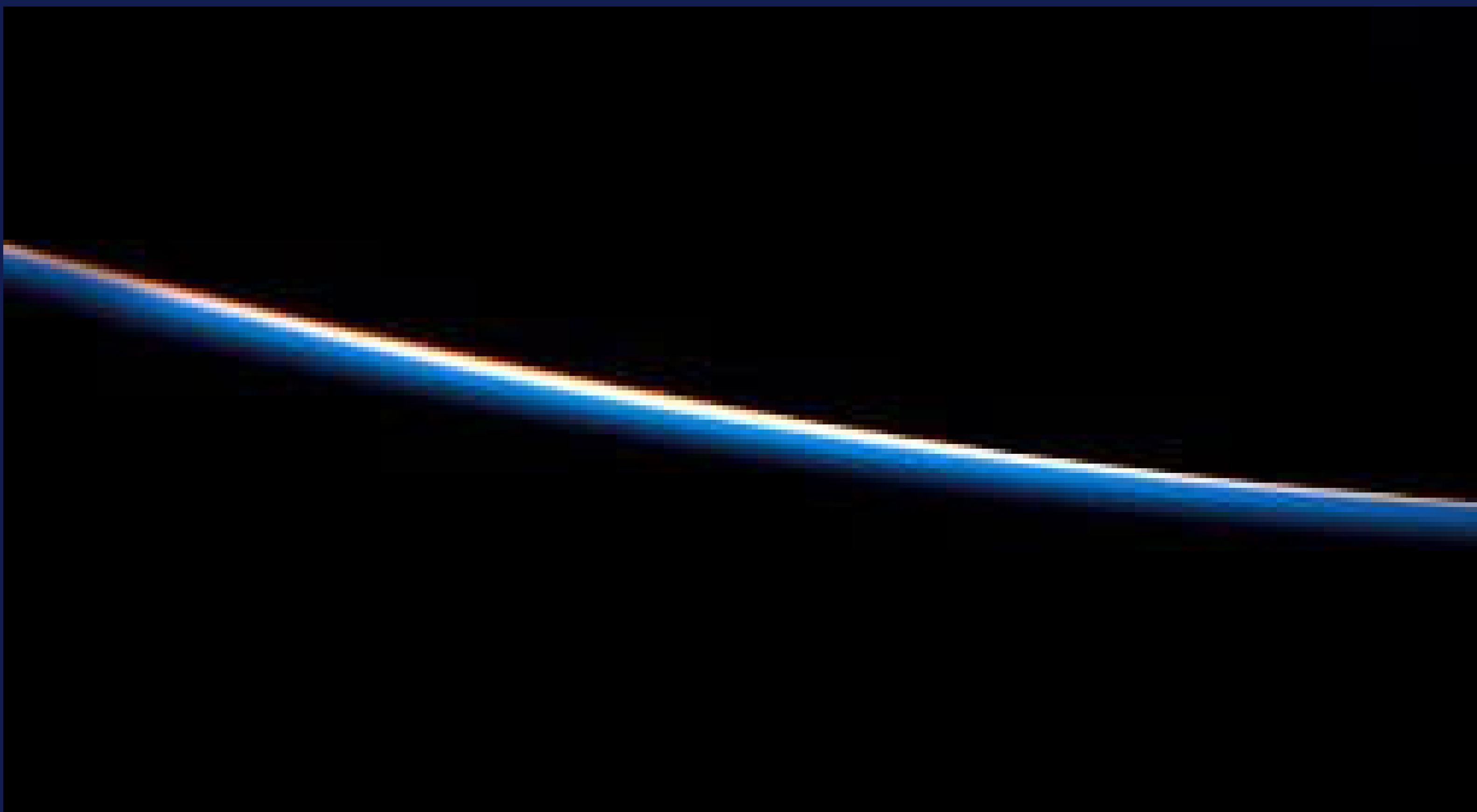
Approaches to palliative care, from a medical perspective, are typically recognized as a point at which all feasible medical treatment options have been exhausted, and disease progression appears inevitable. The primary objective shifts towards enhancing the quality of the remaining life. In most Western practices, the decision-making process is influenced not only by available treatment options but also by factors such as patient age, disease stage, and responses to treatment.[11,12]

In operational space environments, a palliative care option may be considered due to the inability to treat an individual's illness or injuries over an extended, undefined period or the inability to initiate treatment and deliver the standard support or follow-up treatments to ensure longevity.

Approaches to Death, Assisted Death

Palliative care in contemporary medicine may be regarded as disease management rather than cure, and it is typically administered utilizing a broad spectrum of medications. Established protocols, formulated before launch by flight surgeons and directors, specify the selection of medications to be carried during flight and their designated uses.[13,14]

It is recommended that this discussion, along with future guidelines, considers the attitudes of the patient and crew towards palliation, encompassing both cultural and ethical perspectives.[13]



Assisted dying presents a complex issue across many cultures, evoking emotional responses to disease, illness, and death. It is an unavoidable reality that space exploration entails significant risk and that the space environment is highly hostile to humans. Despite the inherent dangers and threats posed by the space environment, individuals, corporations, and nations will continue to pursue space exploration.

A discussion and review of cultural norms and attitudes towards death should be initiated, with recognition that some cultures may be more accepting of death than others, and this may influence their perspectives on treatment options and the preservation of life.[15]

On Earth, where most disease progression and trauma are well understood, guidelines have been established based on extensive clinical experience to assist clinicians: a) in determining when to discontinue treatment; and b) in providing a balanced decision-making environment to support assisted dying for individuals who meet a defined set of legal criteria.[16-21]

The decision-making process for an isolated physician necessitates established guidelines and medico-legal clarity that are recognized by the international spacefaring community. An examination of existing medical guidelines did not reveal a developed protocol or guideline appropriate for the operational space environment.[22-23]

The reviewed medico-legal framework did not account for isolated decision-making or the absence of access to unlimited medical supplies. Both scenarios—namely, isolated clinicians and limited resources—are plausible outcomes of humanity's forthcoming endeavors into space.

However, an unresolved issue remains concerning the legal validity of AI advice and its incorporation into the decision-making process.

Can AI Lighten the Decision Burden?

AI and Space Medicine

In humanity's envisioned future, AI medical assistants are anticipated to transcend the limitations of current generative models, which are often prone to the inaccuracies that practitioners experience today. With proper training and rigorous testing, AI systems such as Large Language Models (LLMs), Rules-Based AI, and deep learning platforms could independently analyze clinical data and provide advice to isolated attending physicians.[22-24]

Discussions concerning the limitations that may influence the application of AI within space environments are beyond the scope of this paper. Although this is a worthy subject for future consideration, it may affect the data and processing capacity accessible to AI systems in space. As previously noted, the validity and legal status of advice generated by AI systems have yet to be firmly established.[24]

Operational AI

Assuming the existence of an operational and competent AI medical assistant, the scope of its capabilities could be utilized to balance the treatment needs of a patient, thereby presenting the clinician with a logical spectrum of clinical treatment options and outcome scenarios. These considerations would encompass the operational environment, available clinical resources, medications, and their performance within it.[25-26] Ideally, any AI analysis would incorporate all potential medical outcomes, including statistical probabilities of recovery, disability, and morbidity (including adaptability within the space environment), as well as a realistic mortality rate.[27-30]

The Working Group recognizes that balancing this information against a potential rationing of medical resources and patient treatment, crew health, crew longevity, and mission parameters may be considered offensive to some. It is crucial to acknowledge that the duration of the flight, resources available at the destination, or the time required to reach the nearest supportive medical facility may influence the allocation of resources necessary for the resuscitation of a single patient versus the needs of the majority of the crew's future.

Generative vs Deductive AI

Most current AI systems are generative models that simulate reasoning through learned statistical patterns rather than executing formal deductive logic. These learned patterns lack consideration or insight into clinical or medical correctness. At this stage of development, such systems cannot be regarded as suitable for functioning as independent or adjunct clinical opinions.[31] The development of deductive medical AI LLMs involves more than merely ensuring high-quality data input.[2,3] For a system to become a holistically useful tool for clinicians in the space environment, the LLM's or AI models must possess reasoning flexibility, which has not yet been achieved.

It is anticipated that future advancements in computing, AI language models, and training methodologies will overcome the current limitations for space operations. The Working Group concludes that future AI medical models may help significantly in these situations, alleviating the clinical decision-making burden by providing holistic and complete analysis for the clinician to consider.[2]

Recommendations

The Working Group recommends utilizing the vehicle established under the Artemis Accords to engage with signatory countries, with the objective of establishing uniform clinical decision-making approaches rooted within a medico-legal framework that considers the implications of AI guidance in isolated clinical environments. The following actions are advised:

1. It is recommended that a program be initiated by the 61 Artemis Accords signatory countries to develop a shared training module for astronauts, crew, payload specialists, passengers, and future settlers regarding medical decision-making in LEO, on the Moon, Mars, or other extraterrestrial settlements, as well as during the journey period aboard spacecraft.

   The module should be integrated into spaceflight training, with a minimum of three revisits during the training period to discuss operational aspects such as clinically independent decision-making, the medical decision-making process, and the challenges associated with decision-making in remote environments.

2. Discussions should be initiated regarding Do Not Resuscitate (DNR) orders and various levels of invasive treatments. Consent should evolve into a deliberate, thoughtful, and interactive process during training and preparation for the space environment.

   All DNR and treatment directives should be documented in clear, plain English, adhering to the language conventions of aviation.

3. A second, collaboratively developed module should be made accessible to astronauts, crew members, payload specialists, and future settlers. This module should be provided as a self-paced educational package that discusses the clinical decision-making process developed in response to the space environment and its inherent restrictions.

   It is of significant value for astronauts, crew, and payload specialists—whose careers will be conducted in an extraterrestrial environment—to review, comprehend, and engage with this information, including discussions with their NoK and families.

4. These modules should be aligned and represent a consensus among the 61 Artemis Accords signatory countries, with provisions for review should new member states join the Accords. It is recommended that all 61 signatories agree in principle that these are important concepts, and that explicitly agreed-upon 'Rules of Engagement may be tailored to crew-specific considerations, taking cultural norms into account.

   Furthermore, it is advised that individual country decisions and protocol should not be subject to veto by nations with differing cultural perspectives or lacking a history of successful human space launches. Multi-country missions and crews should retain the freedom to negotiate protocols for each mission or operational period.

   This process aims to reduce confusion or misinterpretation of the clinical decision-making process, which, by necessity, will at times involve complex judgments for both the patient and the clinician. It endeavors to foster an environment characterized by normalized and transparent discussions concerning clinical decision-making within space environments.

5. Signatory countries to the Artemis Accords should generally reach consensus on the methodology and approach to medical decision-making, acknowledge the burdens imposed on decision makers, and collaborate towards maintaining a cohesive and cooperative crew.

   It is also important to consider the likelihood of decreased health and increased illness among the crew, and the potential impact this may have on mission success if resources are depleted.

6. It is recommended that a ‘Good Samaritan Law’ be incorporated into mission protocols to safeguard individuals attending the mission, regardless of whether they are medical practitioners. Emphasizing the primacy of patient care, those performing their duties diligently should be protected from legal liability during the decision-making process, except in cases of gross negligence.

   Consideration should be given to a model analogous to various Australian Good Samaritan legislation.

7. It is essential to recognize and accommodate AI medical assistance, encompassing both generative and deductive LLMs as well as other learning models. Each model has the potential to evolve, offering a distinct set of capabilities, which may influence clinical operating advice in a space environment.

   In situations where AI offers guidance and directives regarding clinical outcomes, it is recommended that the AI employed be deductive, with thoroughly tested high standards, while maintaining established moral and clinical boundaries.

Furthermore, the discussion should be expanded to include considerations of the legal status of such advice and the protection of clinicians who may act upon it when provided by an AI system.

Criteria regarding the technical specifications, such as the type of LLM used, the quality of AI training and knowledge base, and the programming parameters for statistical analysis, should be defined.

Conclusions

In the Western medical system, ethical medicine is a blend of informed moral and cultural decisions, usually focused on individual patient outcomes. In the space environment, the situation may be reversed. Clinical decision-making parameters may be replaced with considerations for medical resources, crew health and longevity, and mission outcomes, with their priorities ranked higher than an individual patient in need of medical care.

This document acknowledges, identifies, and forecasts potential future challenges faced by individuals in the space environment, particularly concerning decision-making processes related to a crew members' illness, injury, or caregiving. Solo or isolated clinical decisions in anticipated remote work situations may contribute to social discord. This situation could lead to the socio-psychological exclusion of individuals from typical crew functioning and interactions, thereby risking negative impacts on mission success.

The authors acknowledge, with sensitivity, that the subject of discussion may include some distress; however, they contend that it is preferable to be prepared for difficult discussions and circumstances rather than confront these themes when such decisions must be made. The circumstances of social isolation may lead to individual harm, thereby potentially jeopardizing overall crew health and mission success.

This discussion paper emphasizes several concerns associated with complex clinical decision-making within the space environment. It contrasts the fundamental differences in managing health outcomes on Earth with the challenges encountered in altered gravity, spacecraft, and extraterrestrial environments. The authors recognize a potential role for artificial intelligence in mitigating the burden of treatment decision-making for individual physicians or healthcare providers. Furthermore, the authors propose recommendations to minimize the risk of physiologically detrimental crew dynamics.

The Artemis Accords could serve as a mechanism to standardize a consistent, mutually accepted methodology and approach to medical decision-making across diverse cultures and religious beliefs.

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