Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Letter to the Editor

Letter Regarding "How to Manage Head Injury With COVID-19 Pneumonitis On Mars? Rare But High Impact Complex Medical Emergencies In Space"

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We read with interest the Robertson *et al.*'s[1] research on future deep space exploration and stationary missions on Mars. Robertson and colleagues identified several most impactful conditions in the otherwise well selected and extremely fit population of astronauts. Perhaps the most helpful is the identification of the most dangerous complex emergencies, for example where differences in skill mix, issues with communication, situational awareness and equipment shortages may further jeopardise the success of the mission.

The authors concluded that high-dependency conditions such as shock, radiation sickness, head injury, and toxic exposure may occur simultaneously and thus compound the danger, especially when more than one crew member is affected. We believe that another potentially critical complication may arise from an infectious disease, which may be a common occurrence in Martian medicine, as pathological microbiological changes have been observed in astronauts.[2-5]

The recent COVID-19 pandemic has demonstrated how infectious diseases can quickly spread and complicate the management of emergencies, even in a young and fit population.[6] Pathogens in space could be more infectious and difficult to eradicate due to extra-terrestrial contamination,[7] proliferation in weightlessness,[8] thicker cell walls and more antibiotic resistance.[9] There may also be other compounding biohazards on Mars.[10]

Thus, it is important to consider infectious disease complication in any medical emergency on Mars. Treating all cases as a potential bio-hazard (similarly to current terrestrial practice) may be necessary and should be included in future research and training simulations. As an example scenario, a crew member may sustain a head injury whilst performing extravehicular activities. The injured person(s) would have to be retrieved, managed, and observed in a by-default isolated chamber on the station. Crew members assisting in their care would need to wear suits with "clean" oxygen supply and submit all their equipment for decontamination after duty.

Given the now increased requirement for personal protective equipment on earth due to COVID-19, preparation for managing head injury on Martian surface must include the potential for dealing with such a pathogen during a Long Duration Exploration Mission (LDEM). In addition to the basic requirements already identified by NASA,[11] the following should also be included:

- isolation and decontamination facilities (chemical, radiation),
- provision of air filters (heat and moisture, micro-nets),
- separated flow circuits (compartments).

Our COVID-19 complicated head injury scenario also exposes the challenges of the physics of LDEM on Mars. The gravity on the planet is 1/3g, which causes deceptively low weight and subsequent inadvertent acceleration of objects, and can lead to more traumatic head injuries.[12] In this setting, fluid redistribution alone is equivalent to class I haemorrhage, even before injury.[13] This is further complicated by cardiac atrophy, beta receptor oversensitivity, altered neuroendocrine function and immunosuppression that is already observed in space travellers.[14-16]

Logistics will also be difficult. Supplies take 8 months to arrive, radio communication is delayed by almost an hour both ends, and the potential of early retrieval of an injured astronaut is almost non-existent ATLS management would have to be initiated independently,[17] as first instructions from mission control will arrive with at least 45 min' delay. Imaging provision will be limited,[18] and medicine supply shortages may arise. For example, an early administration of antimicrobials with CNS cover may be indicated in some cases, which will be difficult with current stock levels (e.g., there are only 100 tablets of amoxicillin 500 mg and 60 tablets of valacyclovir currently on international space station medicine pack[19]).

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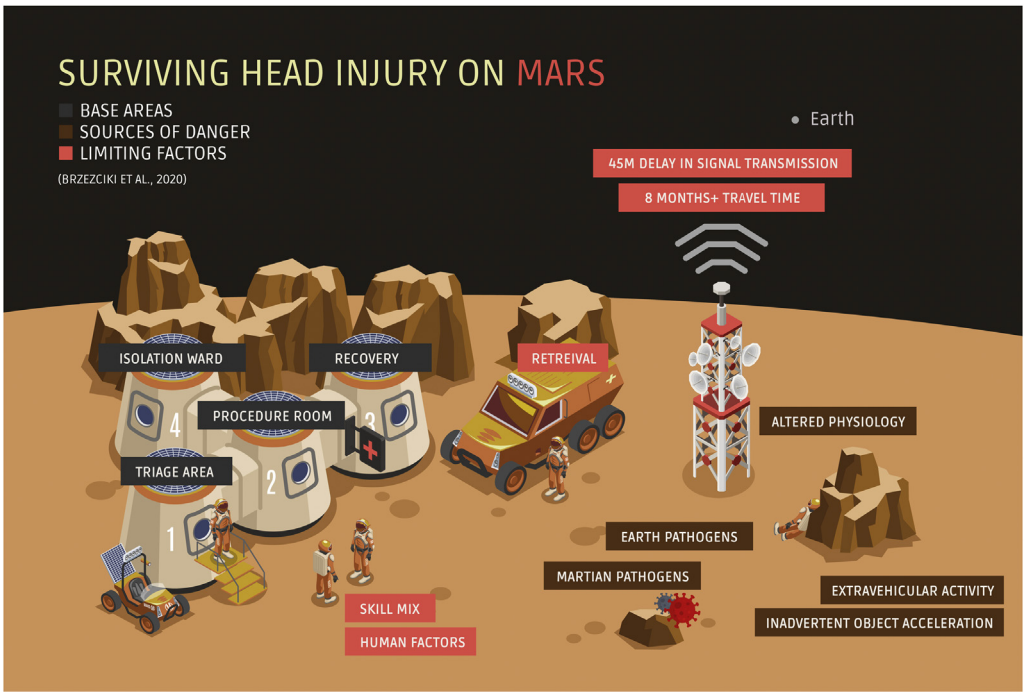

Fig – Summary of challenges to a hypothetical scenario of a complex medical emergency (head injury complicated by infection) on Mars. Base areas (gray: 1 to 4) could be turned into four temporary medical areas, all separated by "clean" and "dirty" oxygen circuits. Additional filtration strategies can be employed, for example by heat and moisture exchange barriers, ionising radiation, and chemical sterilisation. The Martian environment poses several dangers (brown): known (physiology, atmosphere, gravitation, terrestrial microbiology, radiation) and unknown (martial pathogens, random catastrophic events). The situation can be further complicated by factors simulated by Robertson *et al.*, 2020 (pink). (Color version of figure is available online.)

The COVID-19 head injury example may seem like a very unorthodox scenario, yet it exposes crucial infectious, physical and logistical difficulties that may be encountered during an LDEM to Mars (Figure). Extra-terrestrial pathogen complications will almost inevitably arise and it is imperative that research such as Robertson *et al.* is undertaken with than in mind. It would be advisable to train future astronauts in managing traumatic injuries with physiological parameters set at the Marian level, to test human factors with a delayed communication or to attempt to imitate the threat of COVID-19. These rare but potentially catastrophic events must be planned for if an LDEM to Mars is to succeed.

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