Enhancing Astronaut Resilience: The Role of Elevated ROS in Adapting to Space Radiation

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ABSTRACT

The microgravity environment and high radiation levels in space lead to a significant increase in reactive oxygen species (ROS) production compared to Earth, which can have detrimental effects on astronaut health over time. This study examines the hypothesis that high levels of reactive oxygen species (ROS) in living organisms in space may aid pre-selected astronauts' cells in adapting to the intense radiation encountered during missions to Mars and beyond. By looking at evolutionary biology and past radiation events like the Chernobyl disaster, we suggest that increased ROS could trigger adaptive responses similar to those seen in radiation-resistant organisms such as tardigrades. This paper explores the dual nature of ROS as both harmful agents and vital signaling molecules, evaluating their potential to enhance DNA repair, boost antioxidant defenses, and alter mitochondrial metabolism. We aim to see if managing ROS could be a strategy to prepare astronauts' cells for space travel, using cytogenetic tests to find individuals with strong adaptive responses.

Keywords

Reactive Oxygen Species; Space; Astronauts; Adaptation; Radiation; Microgravity

Introduction

The idea that higher levels of reactive oxygen species (ROS) in space could help astronauts adapt to radiation is intriguing. It draws parallels to early life on Earth, where high radiation levels spurred evolution by increasing genetic diversity. After the Chernobyl disaster, we saw greater genetic diversity in species like *Daphnia magna* and *Daphnia plex*, which became more resilient to oxidative stress. These historical examples suggest that stress-induced changes could lead to significant biological adaptations. Applying this concept to space travel, where astronauts face extreme radiation and microgravity, suggests that higher ROS levels might be beneficial.

Adaptive Mechanisms and Cellular Responses

As illustrated in Figure 1, the radioadaptive response (RAR), or adaptive response (AR), is where exposure to a low dose of ionizing radiation makes cells more resistant to higher doses later on [1, 2]. This involves several mechanisms, including improved DNA repair and stronger antioxidant defenses. As cells adapt their biochemical pathways to manage oxidative stress, changes in enzyme functions and gene expression

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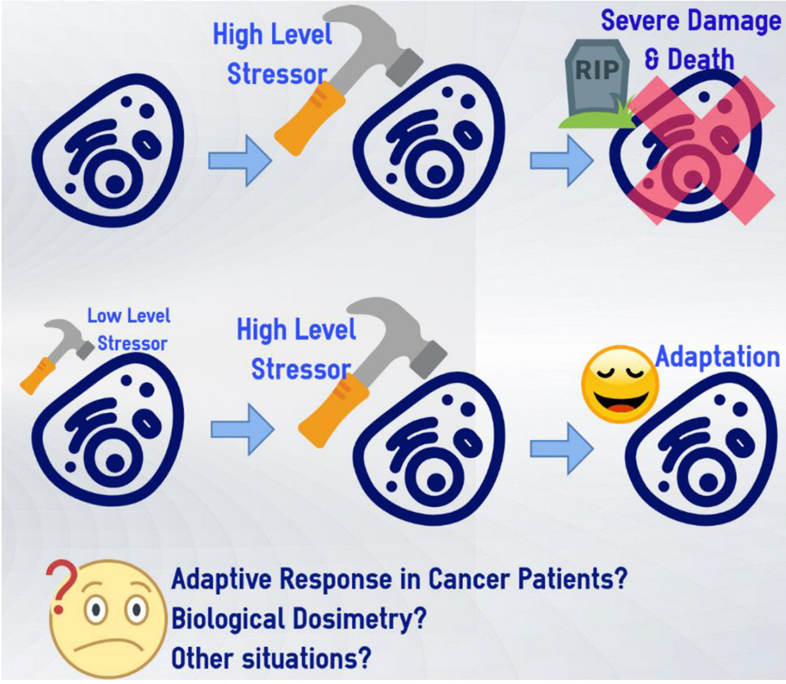

Figure 1: Adaptive response. Exposure to a low dose of ionizing radiation induces an adaptive response in cells, enhancing their resistance to subsequent higher doses of radiation.

occur. In highly radiation-resistant animals like tardigrades, adaptations include stress proteins such as Hsp70, which help maintain genomic stability and prevent cell death. Similar mechanisms might help astronauts become more resilient to the challenges of space. Space radiation poses significant health risks, including cancer, central nervous system effects, and acute radiation syndromes, making adaptive responses a potentially effective strategy to mitigate these risks.

Methodology for Astronaut Selection

Radioadaptive response could enhance radiation protection for astronauts. By tapping into the body's natural defense mechanisms, we might reduce the harmful effects of space radiation, ensuring the safety and health of crew members on long missions. Building on the work of Mortazavi et al. [2-7], this paper suggests evaluating the adaptive response of potential crew members through cytogenetic tests before long-term missions (Figure 2). This involves exposing astronauts' blood lymphocytes to a low dose followed by a high dose of radiation in vitro to assess their adaptive response. Cells with better radioresistance and ROS scavenging capabilities during chronic oxidative stress would likely protect astronauts from sudden increases in radiation due to large solar particle events.

As illustrated in Figure 3, the concept of utilizing higher levels of ROS to enhance astronauts' resilience against space radiation presents a promising avenue for preparing humans for extended missions beyond Earth. However, the application of terrestrial models to space conditions and the understanding of ROS behavior in extreme environments necessitate meticulous evaluation and empirical validation.

Limitations

While this hypothesis is supported by scientific principles and studies, it simplifies the complex effects of radiation on biological systems. Space radiation, a mix of high-energy protons, heavy ions, and secondary

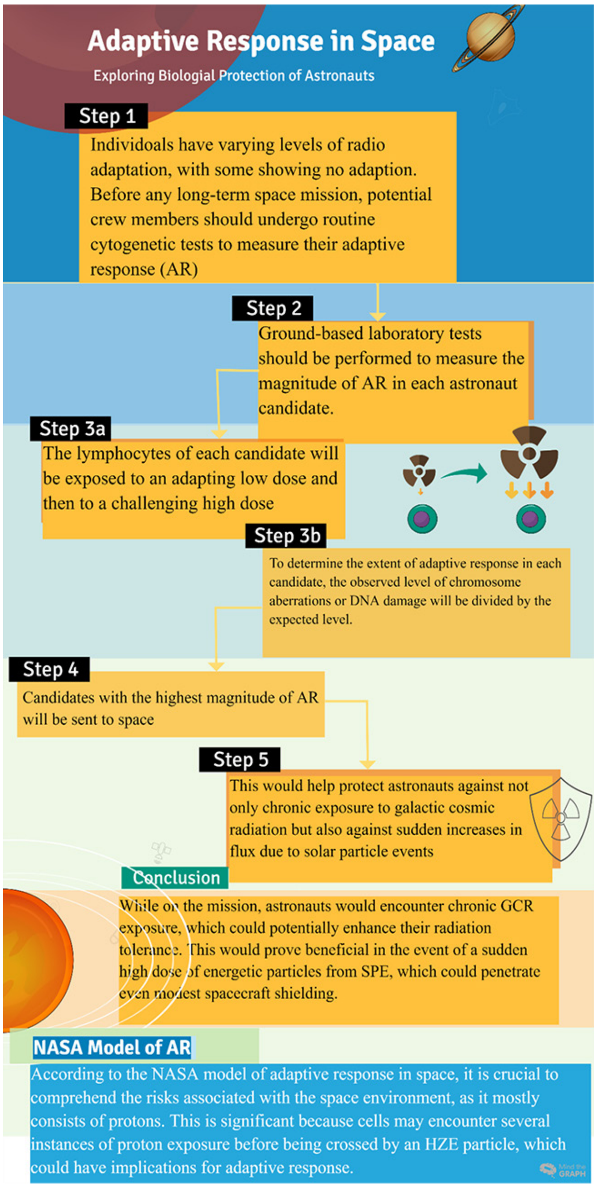

Figure 2: According to methods suggested by Mortazavi et al., before long-duration space missions, astronauts' lymphocytes could be exposed to controlled low or adapting/priming doses of radiation (in vitro). This pre-exposure would be done before exposure to a large or challenging dose to evaluate the magnitude of adaptive responses in each candidate. This in vitro test could help the selected astronauts' bodies better handle the higher levels of cosmic radiation or large solar particle events encountered in space.

radiation, is a unique challenge not directly comparable to terrestrial radiation. Additionally, while ROS might help with radiation adaptation, they can also cause DNA damage and cell death, highlighting their dual role as both beneficial and harmful agents.

Conclusion

The idea that higher ROS levels could boost astronauts' resilience to space radiation offers a new way to prepare humans for long missions. However, applying terrestrial models to space and understanding ROS behavior in extreme conditions require careful evaluation and empirical validation. Future research should focus on controlled experiments to determine safe thresholds and mechanisms of ROS-mediated adaptation in space. Better understanding ROS dynamics in space could significantly improve strategies to protect astronaut health on missions to Mars and other destinations, ensuring the well-being and effectiveness of those exploring this final frontier.

Authors' Contribution

SAR. Mortazavi and SMJ. Mortazavi conceived the idea. They also supervised the study. M. Paakrou and SAR. Mortazavi drafted the manuscript. All the authors read, modified, and approved the final version of the manuscript.

Conflict of Interest

SMJ. Mortazavi, as the Editorial Board Member, was not involved in the peer-review and decision-making processes for this manuscript.

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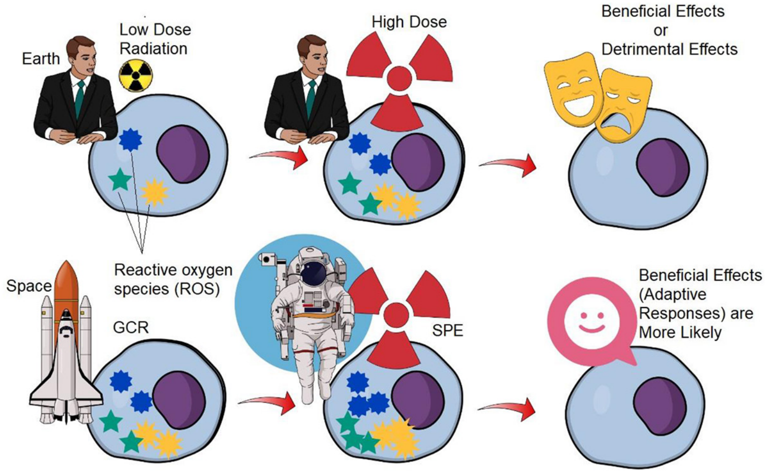

Figure 3: Potential benefits of elevated ROS. Some studies suggest that controlled increases in ROS might enhance cellular repair mechanisms or activate adaptive responses that could mitigate radiation damage. (ROS: Reactive Oxygen Species, GCR: Galactic Cosmic Radiation; SPE: Solar Particle Events)

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