Is the Adaptive Response an Efficient Protection Against the Detrimental Effects of Space Radiation

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Abstract

Exposure to high-energy neutrons, protons and HZE particles during a deep space mission, needs an efficient protection against the detrimental effects of space radiation. Recent findings concerning the induction of adaptive response by neutrons and high cumulative doses of gamma radiation in human cells have opened a new horizon for possible implications of adaptive response in radiation protection and especially in protection against detrimental effects of high levels of radiation during a long-term space journey. We demonstrated significant adaptive response in humans after exposure to high levels of natural radiation. Individuals whose cumulative radiation doses were up to 950 mSv, showed a significant adaptive response after exposure to 1.5 Gy gamma radiation. These doses are much lower than those received by astronauts during a six-month space mission. Screening the adaptive response of candidates for long-term space missions will help scientists identify individuals who not only show low radiation susceptibility but also demonstrate a high magnitude of radioadaptive response. In selected individuals, chronic exposure to elevated levels of space radiation during a long-term mission can considerably decrease their radiation susceptibility and protect them against the unpredictable exposure to relatively high radiation levels due to solar activity.

Keywords: Space radiation, adaptive response, chromosome aberrations.

Introduction

In recent decades, humans successfully experienced relatively long time space missions. No doubt, in the near future deep space journeys as long as a few years will be inevitable. Despite current advances, there are still some great problems that limit the duration of such long-term space missions. Radiation risk due to exposure to high levels of cosmic rays and the effects of microgravity are clearly the most important problems that need to be solved before a long-term

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space mission. Reitz *et al.* (1989) have reported that microgravity increases the radiation susceptibility of living organisms by a synergistic effect. If this is true, the radiation risk would be considerably increased. The four major components of space radiation are gamma rays and electrons, high-energy protons, high-energy heavy ions and neutrons (Edwards 2001). The high LET component of space radiation, especially neutrons, is the major contributor to genetic risks (Grahan 1983). Adaptive response, that is an increased radioresistance in cells or organisms exposed to a high challenging dose after exposure to a low adapting dose, can considerably reduce the radiation susceptibility of individuals. It has recently been shown that neutrons can induce adaptive response in Chinese hamster V79 cells (Marples and Skov 1996) or human lymphocytes (Gajendiran *et al.* 2001). These findings, if confirmed by similar adaptive response experiments with high-energy protons and heavy ions, can reduce the risk of long-term stay of human in space.

Adaptive Response and New Horizons in Radiation Protection

During the past two decades worldwide studies on the different aspects of adaptive response and recognition of its positive health effects have lead to a realistic assessment of the risk of radiation. We previously shown that in high background radiation areas (HBRAs), cultured human lymphocytes of the inhabitants whose cumulative radiation doses were as much as 170 times more than those of a nearby control area (2,550 mSv and 15 mSv respectively) when subjected to 1.5 Gy challenge dose, were significantly more radioresistant to chromosomal damage compared to the residents of the control area (Mortazavi *et al.* 2001, Ghiassi-Nejad *et al.* 2002 and Mortazavi *et al.* 2002). What is important about these findings is the apparent relationship between the degree of adaptive response (indicated by the k-value) and cumulative lifetime dose among the study participants. The radioadaptive response of the residents of HBRAs was more pronounced (lower k values) at higher cumulative doses except for 2 residents, whose cumulative doses were much higher than the others. That is, increased dose from natural radiation decreased the radiation sensitivity of the cells.

The following factors explain the importance of the radioadaptive response observed in the residents of high background radiation areas of Ramsar:

1. We indicated that the individuals whose cumulative radiation doses were up to 950 mSv, showed a significant adaptive response after exposure to 1.5 Gy gamma radiation. These doses are much lower than those received by astronauts during a six-month space mission. It has been reported that astronauts' absorbed dose measured by physical dosimetry after a 6-month mission was 90 mGy. The biological dose ranged 95–455 mGy in different astronauts (Testard *et al.* 1996).

2. Our study suggests that high levels of natural radiation may enhance radiation-resistance in non-cycling lymphocytes. As the majority of our lymphocytes are in the resting phase of the cell cycle (G_0), any implication of radioadaptive response in radiation protection strongly depends on the possibility of induction of radioadaptive response in G_0 stage.
3. Adaptive responses have been usually observed by exposing the cells to a low dose radiation in the range of 1–10 cGy. These doses are considerably lower than the lifetime doses that induced adaptive response in the inhabitants of HBRAs of Ramsar.
4. It was suggested that aging could abolish the adaptive response (Gadhia 1998). Our findings suggest that aging did not influence the induction of radioadaptive response.

Identifying Radioresistant vs. Radiosensitive Human Subpopulations

In space radiation studies, it has been widely reported that the identification of subpopulations that are genetically susceptible to ionizing radiation is of great importance. Based on these reports, choosing individuals who show an increased radiosensitivity for a deep space mission considerably increases their cancer risk. In human, only the gene for ataxia telangiectasia (AT) has been proved to control the radiation susceptibility (Hall *et al.* 2001). The following evidence clearly shows that identifying the radiosensitive human subpopulations has some great disadvantages:

1. It should be noted that only 1–2% of the population is AT heterozygotes (Smilenov *et al.* 2001).
2. At present, screening the population for identifying AT due to high cost and the need for modern equipment seems to be impractical.
3. Even AT homozygotes, which are extremely radiosensitive, can show adaptive responses (Seong *et al.* 1995).

Conclusion

Astronauts are irradiated with high levels of radiation. Solar activity is currently unpredictable and specially space-walking astronauts and astronauts who participate in long-term space missions may receive high doses of radiation in a short time. Recent findings concerning the induction of adaptive response by neutrons and high cumulative doses of gamma radiation in human cells have opened a new horizon for possible implications of adaptive response in radiation protection. Screening the candidates of long-term space missions by in vitro adaptive response studies identifies the individuals who show low radiation susceptibility and demonstrate a high magnitude of radioadaptive response. In these individuals, chronic exposure to elevated levels of space radiation during a long-term mission can considerably decrease their radiation susceptibility and protect them against the unpredictable exposure to relatively high radiation levels caused by solar activity.

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