Deep space missions and the issue of overcoming the problem of space radiation

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► ***Short report***

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Received: April 2013
Accepted: June 2013

Int. J. Radiat. Res., July 2013; 11(3): 199-202

ABSTRACT

As a member of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), Iran has a long-term space exploration program. Space radiation is one of the challenges facing humans when they go outside Earth's protective atmosphere and magnetic field. Space is an environment that the cardinal principles of radiation protection; i.e. time, distance and shielding cannot be effectively applied. On the other hand, well-known limitations of physical shielding prompt us to explore biological methods for inducing radioresistance during space missions. Screening of the candidates of long-term space missions by ground-based *in vitro* adaptive response studies might be helpful. It has recently been shown that the detrimental effects of exposure to protons and HZE particles can be prevented by some dietary supplements. Interestingly, in contrast with radioprotectors, these dietary supplements can prevent radiation induced detrimental effects even when applied several days after exposure to radiation. It seems that finding appropriate *radiation mitigators* with a *post-exposure* time window in excess of 24 hours will be a critical goal in planning future manned space missions. In this paper, the advantages of biological shielding over current well defined physical shielding will be discussed.

Keywords: *Space Radiation, Astronauts, Adaptive response, Long-term space travel, cosmic radiation, Radiation Protection, Shielding.*

Iran's space exploration program

Iran is one of the 24 founding members of the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS), which was set up in 1959. Iran launched its first indigenous satellite, Omid (a Persian word that means Hope), in 2009. Using the indigenous Kavoshgar-3 (a Persian word that means explorer) carrier, Iran also sent its first bio-capsule containing living creatures into the space in February 2010 [(1)]. As a member of COPUS, Iran has an extensive space exploration program that includes the cardinal goal of placing a human in space in a very near future. On January 28, 2013 IR Iran reported launching a live monkey into space and recovering it alive. The monkey was strapped down in the Pishgam (a Persian word that means pioneer) capsule and launched aboard a Kavoshgar rocket. According to official news agency IRNA, the rocket reached a height of more than 120 km (75 miles) and returned its shipment intact [(1)]. The launch of Kavoshgar (a Persian word that means explorer) and its retrieval is believed to be the first step towards sending humans into space within the next five to eight years. The choice of a monkey was based on its closely relation to humans. The former Soviet Union chose to use dogs for its space flight test. Laika, a stray dog that was the first animal to fly in space, was flown aboard Sputnik-2 in 1957. In contrast with the monkey used in IR Iran's space flight test, the Sputnik-2

spacecraft was not designed for retrieving and the overheating which occurred within just a few hours of reaching the orbit, killed Laika.

Limitations of physical shielding and advantages of biological shielding

Exposure to space radiation is believed to be an important barrier to space exploration [2]. Astronauts beyond the protective barrier provided by the magnetic field of the Earth, will be exposed to very energetic particles particularly in lightly shielded spacecrafts or during extra-vehicular tasks [3]. Galactic Cosmic Rays (GCRs) and Solar Particle Events (SPEs) are two basic sources of Space radiation. SPEs occur in an irregular manner and are composed primarily of low- to moderate-energy protons, while isotropic GCRs are dominated by protons [4]. Some light weight materials have been used to protect against radiation in manned space missions. Limitations of physical shielding such as extremely high cost of transporting heavy structures into space and their incapability to provide adequate shielding against heavy ions at an appropriate thickness [5]. Limitations of physical protection and also measurement and analysis of radiation dose from various sources lead us to find biological methods for increasing radioresistance during space missions. There has been an extensive search for chemical radioprotection since 1948 [6]. Since then various drugs were introduced as potent radioprotectors, the best of them amifostine or WR2721. However, these types of radioprotectors are mainly effective against low LET ionizing radiation not neutrons or heavy charged particles in space. On the other hand, side effects of these drugs at high doses for inducing appropriate protection are a major limitation. It should be mentioned that drugs such as amifostine should be intravenously injected 15-30 minutes prior to irradiation which is also a major limitation in space fight. There is search for radioprotectors with long lasting activity and oral administration such as antioxidants and antagonist H2 histamine receptors which proved effective both *in vivo* and *in vitro* against gamma rays and also low doses of neutrons [7-10]. These drugs can be easily administered orally. However, these drugs should be tested against heavy charged particles and high doses of neutrons as well to prove their protective efficacy for astronauts.

Observation of *in vivo* adaptive response in radiation workers [11, 12] has speculated that adaptive response studies may help choose astronauts for long-term space travel [13]. Mortazavi *et al*. stated that screening of the candidates of long-term space missions by ground-based *in vitro* adaptive response studies before any mission identifies the individuals who show susceptibility to low levels of ionizing radiation and reveal high magnitudes of radioadaptive response [14]. Therefore, in these individuals, chronic exposure to high levels of space radiation during any long-term space mission will significantly decrease their radiation susceptibility and protect them against the unpredictable exposure to intense radiations caused by possible solar activities [13]. A recent report based on animal studies, radiofrequency-induced adaptive response is shown as a method for decreasing the risk of infection during deep space missions [15].

New paradigm in biological shielding

As reported by Shiver in 2008, space is an environment that cardinal principle of radiation protection; i.e. time, distance and shielding cannot be routinely applied [16]. The time cannot be reduced since interplanetary space missions such as a Mars mission will take several months. On the other hand, distance cannot be reduced since the galactic cosmic radiations (GCRs) are isotropic and the solar particle events (SPEs) originate from the sun. In this light, scientists believe that the only practical way to reduce the exposure to high levels of space radiation is passive shielding. However, in contrast with low-LET radiations, shielding cannot always lead to reduced radiation risks of energetic charged particles. Therefore, finding efficient methods of inducing biological resistance in astronauts is of prime interest rather than physical shielding. As mentioned above, traditional radioprotectors cannot be considered as efficient tools due to

many problems and limitations such as their very short time window for application (they *must be administered before exposure*) and toxicity. In 2011, Kennedy and Wan showed that exposure to proton and HZE particle radiation increased a wide variety of detrimental effects including oxidative stress, cytotoxicity, cataract development and malignant transformation (in both *in vivo* and *in vitro* experimental systems). They also showed that some of the antioxidants and dietary supplements which are readily available and have favorable safety profiles can prevent these detrimental biological effects. Interestingly, these dietary supplements were effective in preventing radiation induced malignant transformation in vitro even when applied several days after exposure to radiation [17]. One year before the publication of this report, in 2010 it was also reported that a diet supplemented with antioxidants administered starting 24 h after total-body irradiation is more effective than if given soon after the exposure [18]. It seems that finding appropriate *radiation mitigators* with a *post-exposure* time window in excess of 24 hours will be a critical goal in planning future manned space missions. It's *worth mentioning that* SPEs which are currently unpredictable usually continue from several hours to several days [19]. Therefore, by shifting from conventional radioprotectors to radiation mitigators with a long *post-exposure* time window, astronauts have enough time to assess their radiation exposure, before choosing any therapeutic intervention. On the other hand, they can consult expert scientists on the Earth to make sure if they should use any radiation mitigator [20]. Considering these findings, we believe that a new horizon is opened in inducing biological radioresistance against high levels of radiation due to unpredictable solar particle events.

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