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AUTONOMOUS MONITORING OF ORGAN-SPECIFIC RADIATION DAMAGE IN ASTRONAUTS DURING LONG-TERM SPACE RESEARCH USING SYNTHETIC SENSOR MICROORGANISMS

Abstract

In long-term space exploration, high-energy ionizing radiation exposure causes permanent pathophysiological changes at the cellular level in astronauts. Physical dosimeters cannot determine what damage can occur in the human body and in which organ they can occur. This problem can be eliminated with a system of synthetic sensor microorganisms composed of programmed intestinal bacteria (Bacteroides thetaiotaomicron).In the initial phase, the genetic cassette is injected into a bacterial complex isolated from the astronaut's own microbiota in laboratory conditions. This cassette consists of a radiation sensor (RecA), a tissue damage detector (TLR4/HMGB, logic gates (AND-gate), outer membrane vesicles (OMVs), and a CRISPR-Cas memory module. Later, the prepared bacteria are frozen (lyophilized), placed in oral capsules with a polymer coating resistant to stomach acid, and ingested by the astronaut. The system is activated once the microorganisms have settled in the intestine.Four main stages are observed in this process:Initial Recognition: When radiation hits the bacteria, the RecA protein is activated, which is recorded in the bacterial genome as the start of the process.Tissue Verification: When radiation damages human cells, HMGB1 (DAMP) molecules that leak into the blood are captured by bacteria. This confirms that radiation damages not only the environment, but also the body.Organ Scan: The bacterium releases nanometric external membrane vesicles into the bloodstream and, due to specific structures in the vesicles, collects markers of damage available in the brain, lungs, and liver and carries them back to the intestine.Coding: All collected information is recorded as Spacer in the DNA of the bacteria using the CRISPR-Cas system.There is a double safety mechanism in the system against the risks of genetic modification and mutation. The bacteria are transformed into an "Auxiotroph" that can survive on an artificial amino acid that astronaut takes as a dietary supplement. When the process is complete or an external mutation is observed, the bacterium is destroyed by a specific system occurring in the bacteria. This technology can provide a non-invasive, highly accurate, and organ-specific medical map through the sequencing (DNA reading) of astronaut fecal samples. As a result, thanks to these synthetic sensor microorganisms, it is possible to monitor the health of astronauts during long-term space exploration more effectively and quickly.