Unpacking space radiation to control astronaut and earthbound cancer risk

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Michael Weil, PhD, and colleagues hope to understand how, when and with what outcomes the HZE ions of space radiation cause cancer. Credit: Colorado State University

NASA limits an astronaut's radiation exposures to doses that keep their added risk of fatal cancer below 3 percent. Unfortunately, that ceiling restricts the time an astronaut may spend in space, which in turn restricts the ability to perform longer missions, say a mission to Mars. Now a network of research laboratories seeks to understand the mechanisms and effects of space radiation with the goal of predicting and preventing radiation-induced cancers, both in space and at home. One of these laboratories is that of Michael Weil, PhD, investigator at the University of Colorado Cancer Center and professor in the Colorado State University Department of Environmental & Radiological Health Sciences, whose paper recently published in the journal *Frontiers in Oncology* describes attempts to personalize the assessment of radiation-induced cancer risk in astronauts.

"I have become a bit of a space aficionado, but I suspect the major impact of what we do is going to be for cancer patients," Weil says. This is because high-energy ions similar to the radiation experienced in space is being increasingly used in cancer treatments. Carbon ions are in use to treat cancer patients in Japan and Germany, and similar treatment facilities are in the planning stages in the United States. "The way carbon ions deposit energy is very suitable for hitting tumors while missing healthy tissue," Weil says. However, the same radiation used in cancer treatments presents a risk for the future development of new tumors.

On earth, discovering the cancer risk associated with radiation dose is generally done by noting levels of radiation exposure and later cancer development in large populations of people. For example, "Radiation epidemiologists know the radiation doses received by 120,000 survivors of the Hiroshima and Nagasaki atomic bombings and their health outcomes. With this, we can estimate how much a given dose will increase cancer risk," Weil says.

But the calculation of cancer risk from space radiation is much different. First, space radiation is not the same as radiation on earth. "NASA is most concerned about galactic cosmic radiation and the worst component is HZE ions," Weil says. These ions, composed of atomic nuclei stripped of their electrons and moving through space at near light speed "can punch right through a couple meters of aluminum or right through an astronaut, leaving ionization tracks," Weil says. (The acronym HZE comes from high (h) atomic number (z) and energy (e)). Fortunately for everyone on earth, these HZE ions are deflected by the Earth's magnetosphere. However, the deflection of HZE ions also means that no epidemiological data exists that could ground risk calculations. Instead, determining the risk of HZE ions requires experimental models and technology.

"We don't have access to galactic cosmic radiation on earth, but we do have accelerators," Weil says. The NASA Space Radiation Laboratory on Long Island, NY can simulate the types of radiation found in space. NASA-funded researchers like Weil use the facility to irradiate mice or cultured human cells.

"How effective are these radiations at causing cancer?" Weil asks. "The answer is incredibly effective."

In addition to showing that HZE ions efficiently cause cancer, Weil and colleagues hope to understand how the timing of HZE ion delivery impacts risk.

"For example, maybe every morning when I wake up, I take 81 milligrams of aspirin because it's good for my heart. But if I take a year's dose all at once, that will cause problems." Weil says. We have good data on the effects of acute radiation exposures. However, while the accumulated dose an astronaut receives may be quite high, the dose is generally delivered over time, leading to a lower "dose-rate" and, potentially, less risk than if the same dose had been delivered over a shorter time. And, unfortunately, an accelerator is not capable of delivering low exposure over a protracted period.

"We don't have good experimental ways to approach this question," Weil says. He does, however, note that historical data from uranium miners who are at increased risk for lung cancer from occupational exposure to Radon gas provides clues to cancer risk with lower dose-rate exposures.

Another issue facing investigators is the difference between cancer incidence and cancer mortality.

"NASA is primarily concerned not just with how many cancers will be caused by space radiation, but with how many of these cancers will be fatal," Weil says. Cancer researchers know the incidence-to-fatality ratios of cancers experienced by earthbound populations - they can query a database for, say, the number of lung cancer cases and compare it to the number of lung cancer deaths. However, there is increasing evidence that not only are HZE ions especially good at causing cancer, but that the types of cancer they cause tend to be more aggressive than their counterparts on earth.

When Weil's group "hauled mice to an accelerator facility and irradiated them to produce liver tumors," more of these tumors than expected went on to metastasize to the lung, implying a more aggressive liver cancer. For NASA and potentially for earthling cancer patients, this means that risk assessments have to take into account not only the risk of developing cancer with HZE ion doses, but the higher percentage of these cancers that may be fatal.

The eventual goal of this work is twofold: To more accurately calculate cancer risk to spaceflight crews and provide a better understanding of how HZE ions cause cancer which, in turn, will lead to ways to mitigate this risk.

Ultimately you'd like to "develop a pill you can take that will prevent space radiation from causing cancer," Weil says. "To do that, you have to understand the mechanisms whereby radiation causes cancer."

And so, overall, the goal is to understand how, when and with what outcomes HZE ions cause cancer. In addition to allowing human beings to travel to Mars, solving these questions may make us healthier here at home.

Provided by University of Colorado Denver

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