

# Impact of Particle Irradiation on the Immune System: From the Clinic to Mars

Despite the generalized use of photon-based radiation (i.e., gamma rays and X-rays) to treat different cancer types, particle radiotherapy (i.e., protons and carbon ions) is becoming a popular, and more effective tool to treat specific tumors due to the improved physical properties and biological effectiveness. Current scientific evidence indicates that conventional radiation therapy affects the tumor immunological profile in a particular manner, which in turn, might induce beneficial effects both at local and systemic (i.e., abscopal effects) levels. The interaction between radiotherapy and the immune system is being explored to combine immune and radiation (including particles) treatments, which in many cases have a greater clinical effect than any of the therapies alone. Contrary to localized, clinical irradiation, astronauts are exposed to whole body, chronic cosmic radiation, where protons and heavy ions are an important component. The effects of this extreme environment during long periods of time, e.g., a potential mission to Mars, will have an impact on the immune system that could jeopardize the health of the astronauts, hence the success of the mission. To this background, the purpose of this mini review is to briefly present the current knowledge in local and systemic immune alterations triggered by particle irradiation and to propose new lines of future research. Immune effects induced by particle radiation relevant to clinical applications will be covered, together with examples of combined radiotherapy and immunotherapy. Then, the focus will move to outer space, where the immune system alterations induced by cosmic radiation during

spaceflight will be discussed.

Keywords : protons, carbon ions, immunotherapy, space flight, cosmic radiation, immune response, cancer therapy.

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