Overview of Space Radiation Health Risks with a Focus on Radiation-Induced Cardiovascular Diseases

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INTRODUCTION

Futurist Manned Missions

International Space Station
- ISS-102: Hypercapnia
- ISS-103: Paralysis, sweating, confusion

Lagrange Points
- Design Reference Mission currently being formulated
- Design Reference Mission currently being formulated
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Near Earth Objects
- ISS-104: Paralysis, sweating, confusion
- ISS-105: Paralysis, sweating, confusion
- ISS-106: Paralysis, sweating, confusion

Mars
- ISS-107: Paralysis, sweating, confusion
- ISS-108: Paralysis, sweating, confusion
- ISS-109: Paralysis, sweating, confusion

The Space Radiation Problem

Intimately close calls are the experience of a high LET radiation environment characterized by high-energy cosmic radiation and heavy ions (HICD) as well as secondary protons, neutrons, and fragments produced by shielding and other processes.

High doses (> 5 Gy)

Radiotherapy Data:
- High doses (>5 Gy exposures) associated with damage to the structures of the body and to the coronary, cerebral, and other large arteries including inducing atherosclerotic damage, especially of the pericardium and myocardium, potential embolism, microvascular damage and remodeling of the vascular bed, and damage observed in patients receiving RT as well as in experimental animals (Little 2013).
- Deterministic effect (tissue reaction)
- Mechanism: cell killing or invasion of large # of cells – functional impairment

Low doses (< 0.5 Gy)

Life Span Study, Clinical, and Occupational Exposures:
- Moderate doses (0.5–5 Gy exposures) associated with atherogenesis, micro and macrovascular damage
- Possibly a stochastic reaction
- Mechanisms may involve inflammation and oxidative stress, endothelial dysfunction/vasoreactivity

Risk Projections:
- Data on low doses is confounded by lifestyle factors, claiming interest in the epidemiology data below 0.5 Gy
- Evidence is considered deterministic, with an associated threshold dose; however recent evidence showing risk at lower doses questions this assumption

Low Dose Ranges
- Low doses (< 0.5 Gy) associated with systemic effects, microvascular damage
- Possibly a stochastic reaction
- Mechanism: may involve non-targeted effects, kidney dysfunction, mitochondrial dysfunction, atherogenesis
- Controlling effects are large

Meta-Analysis of Low Dose Studies:
- Low doses (< 0.5 Gy) associated with systemic effects, microvascular damage
- Possibly a stochastic reaction
- Mechanism: may involve non-targeted effects, kidney dysfunction, mitochondrial dysfunction, atherogenesis
- Controlling effects are large

Low Dose (< 0.5 Gy)

Modest Doses 0.5–5 Gy

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Low Dose (< 0.5 Gy)

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Risk Mitigation Strategy

Potential Mechanisms of Radiation-Induced CVD

Potential Mechanisms of Exposures at Moderate Doses

Potential Mechanisms of Radiation-Induced CVD

Potential Mechanisms of Exposures at Moderate Doses

DEGEN RISK SUMMARY

ICRP Recommendations (2012)

Definition of “Threshold Dose”:
- Maximum ICRP 300 threshold defines a “threshold dose” as an exposure below which clinically significant effects do not occur
- ICRP 300 threshold defines a “threshold dose” as ED1 (estimated dose for 1% incidence), denoting the amount of radiation that is required to cause a specific, observable effect only 1% of individuals exposed to radiation.
- ED1 is a significantly lower dose than the baseline levels in unirradiated, age-matched healthy control subjects.
- No radiation-induced vascular disease, to a dose which would increase the already high radiation incidence or mortality by only 1%.
- ED1 does not imply that biological effects occur at lower doses; it merely defines the dose above which a specified effectiveness clinically apparent in a small percent of individuals.

5 Gy may lead to approximately 1% of exposed individuals developing the disease in question within 10 years after exposure. This is in addition to the high natural incidence rate (circulatory diseases account for 30–50% of all deaths in most developed countries).