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

Zarana S. Patel¹, Janice L. Huff², and Lisa C. Simonsen³

¹Wyle Science, Technology and Engineering, Houston, TX 77058
²USRA Division of Space Life Sciences, Houston, TX 77034
³NASA Langley, Hampton, VA

INTRODUCTION

Futurore Manned Missions

International Space Station

- 2.5 person-years 360 days in planning.

Lagrange Points

- Design Reference Mission currently being formulated.
- Design Earth’s magnetosphere and radiation belts.

Near Earth Objects

- Design Reference Mission currently being formulated.
- Design Earth’s magnetosphere and radiation belts.
- Design cosmic ray fluxes are major concern.

Mars

- RBO and beyond: Exposure crown, up to 1000 days.
- Long-term space missions.
- Risk exceed NASA Permissible Exposure Limits (PELs) for cancer, and pose significant non-cancer risks.

The Space Radiation Problem

- Intraosseous wells are exposed to a high LET radiation environment comprising energetic cosmic rays (HZE) as well as secondary protons, neutrons, and fragments produced in shielding and solid.
- Heavy ions are qualitatively different from 3-keV to Gammas-rays high LET: low LET.
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Health Risks from Space Radiation

Risk of Radiation Carcinogenesis

- Possible in-flight, altered cell function due to ionizing radiation, and behavioral changes which may affect performance.
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Risk of Acute (in flight) & Late Central Nervous System Effects

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Risk of Cardiovascular Disease and Other Degenerative Tissue Effects

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Risk of Acute Radiation Syndromes due to Solar Particle Events

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Cardiovascular Disease and Other Degenerative Tissue Effects from Radiation

Risk of Degenerative Tissue Effects:

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Other Health Effects:

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Driving Evidence:

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Risk Projections:

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ICRP Recommendations (2012)

Definition of “Threshold Dose”:

- Previous ICRP 30 Report defined a “threshold dose” as an exposure below which clinically significant effects do not occur.
- ICRP defined “threshold dose” as ED1 (estimated dose for 1% incidence), defining the amount of radiation that is required to cause a specific, observable effect only if 1% of individuals exposed to radiation.
- ED1 effects still occur at the threshold levels in unscreened, age-matched, and sex-matched control groups of healthy individuals, thus significantly increasing their radiation susceptibility.
- ED1 dose may not indicate 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.

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

DRIVING EVIDENCE

Radiotheray Data:

High Doses > 5 Gy

- High doses (>5 Gy exposure) associated with damage to the structures of the heart and to the coronary, cardiac, and other large arteries including mental effects of the heart, microvascular damage, damaged microvascular damage and atherosclerosis of the heart.

Medium Doses 0.5 - 5 Gy

- Moderate doses (0.5 - 5 Gy exposure) associated with microvascular damage and macrovascular damage.

Low Doses < 0.5 Gy

- Meta-Analysis of Low Dose Studies:
  - Low doses (<0.5 Gy) associated with systemic effects, microvascular damage.
  - Possibly a stochastic reaction.

Potential Mechanisms of Radiation-Induced CVD

Dose Rate Effects

- Radiation exposure associated with stroke.
- Increased risk of Elevated Blood Pressure, diabetes, and obesity.

Potential Mechanisms of Exposures at Moderate Doses

Risk Mitigation Strategy

Evidence

Still, there is conflicting data even at moderate dose ranges.

The results of these 11 studies have not been published in a sufficiently uniform format to permit a formal heterogeneity test but still clearly shows that there is substantial heterogeneity between them.

Other challenges for these types of analyses include latency issues, and misclassification of pathological causes of death.

Low Dose Countermeasures

- Countermeasures for the observed trends in most cohorts with these higher dose groups.

DEGEN RISK SUMMARY

- Association between exposure to high doses of low LET (<5 Gy) radiation during radiotherapy to the chest and increased risk for development of cardiovascular disease at late times post exposure is clearly established.
- Atomic bomb survivor data and analyses of epidemiology data provide evidence for elevation of risk at lower doses than previously identified, with significant risks at doses as low as 0.5 Gy.
- Data at low doses is confounded by lifestyle factors, leading to bias in epidemiology data below 0.5 Gy.
- Effects are considered deterministic, with an associated threshold dose; however recent evidence suggesting risk at lower dose questions this assumption.
- Prior risk assessment models were formulated based on recent epidemiology data for lower dose low LET exposures. More risk estimates dependent on research results describing the qualitative and quantitative differences between GCR and gamma-rays.
- Studies at NHEI, with HZE ions and appropriate animals models are required.
- Lack of evidence on radiation quality, disease spectrum, latency and dose rate at low levels of exposures.

The additional mortality and morbidity risks for non-cancer diseases of the cardiovascular system are major concerns because they could increase RED values substantially.