WILL ASTRONAUTS BE AT INCREASED RISK FOR HEART DISEASE FROM SPACE RADIATION DURING EXPLORATORY MISSIONS?

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Space radiation and cardiovascular disease

- NASA actively planning exploratory missions to moon and mars
- Exposure to radiation primary risk for human exploration outside of low earth orbit
- Ionizing radiation travels through living tissues, depositing energy that causes structural damage to DNA
- Space radiation distinct from common terrestrial forms of radiation
- A concern during exploratory missions is the potential impact of space radiation on cardiac function during and after spaceflight
COMPONENTS OF SPACE RADIATION

Galactic Cosmic Radiation

-Heavy charged particles race through the cosmos at 80 percent of the speed of light.
-Crab Nebula—a supernovaremnant

Solar Particle Events

-Consist mainly of particles ejected by the sun, although spaceborne atoms can be swept up, too.
-Solar coronal mass ejection
Iron in the earth’s core produces a magnetic field.
Every naturally occurring element in the periodic table is present in galactic cosmic rays.

GCRs = atomic nuclei from which all surrounding electrons have been stripped away.
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GCRs = atomic nuclei from which all surrounding electrons have been stripped away
Abundance of atomic species in galactic cosmic ray spectrum

Atomic number \( Z \) = number of protons found in the nucleus of an atom
Astronauts live inside shielded structures during exploratory missions.
NASA Space Radiation Laboratory (NSRL)

- Simulates the space radiation environment: high energy ion beams 3 "runs" per year
- Beam line, target area, dosimetry, biology labs, animal care, logistic and administrative support
- Liaison Scientists

Medical Building:
- Gamma-ray source
- Long-term labs and animal facilities
- Liaison scientists and administrative support
Our team at NSRL
DRIVING EVIDENCE

0.5 - 5 Gy

- Atherosclerosis; micro and microvasculature damage
- Endothelial dysfunction; inflammation and oxidative stress

> 5 Gy

- Cell killing and inactivation
- Tissue damage and functional impairment

Gy = unit of absorbed radiation
NASA CREW MISSION DOSES

NASA Experience:
- Single ISS mission approximately 1/10 of Mars mission exposure
- Many crew with multiple missions have accumulated 1/3 of Mars exposure risk

Established rat model of injury after exposure to ionizing radiation

Perivascular cardiac fibrosis

Sham irradiated

10 Gy

Kidney function

Blood urea nitrogen (mg/dL)

Systolic blood pressure (mmHg)

Treatment

Data are means ± SD n = 6/gp * = p<0.05, sham vs 10 Gy
Objectives

• Determine the increased risk for developing degenerative cardiac disease as a result of exposure to representative components of space radiation

• Evaluate permissible exposure limits
Mixed beam of protons, $^{28}\text{Si}$ and $^{56}\text{Fe}$

- Male Wistar rats, 6 months of age
- 1000 MeV protons/n (80% of the total dose), 500 MeV/n $^{28}\text{Si}$ (10% of total dose) and 600 Mev/n $^{56}\text{Fe}$ (10% of the total dose)
- Protons delivered first, $^{28}\text{Si}$ second, and $^{56}\text{Fe}$ last
- Switching times between beams 1-2 minutes each
- Four dose groups: 0.25 Gy, 0.50 Gy, 0.75 Gy and 1.5 Gy, dose rate 50cGy/min
- Sham-irradiated rats as controls
- Risk factors for cardiac disease
- Kidney injury
- Biomarkers of oxidative and inflammatory stress
- Occurrence of cardiac disease
Significant findings

- There have been no deaths associated with any dose of radiation
- Rats exposed to mixed beams of protons, $^{28}\text{Si}$ ions and $^{56}\text{Fe}$ ions showed modest changes in risk for cardiac disease and kidney injury after irradiation
- Increased perivascular cardiac fibrosis at the end of the 270 day follow up period
- Biomarkers of oxidative stress and inflammation increased 30 days after irradiation and decreased 60 days after irradiation with mixed beams
Summary

Our studies are starting to provide an estimation for the occurrence of cardiac disease after exposure to space radiation that will enable evaluation of permissible exposure limits.