Distribution of Plutonium and Radium in the Human Heart

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Since 1968, the U.S. Transuranium and Uranium Registries (USTUR) has studied the biokinetics and tissue dosimetry of uranium and transuranium elements in nuclear workers. For 50 years, the mission of the USTUR has been "to refine dose assessment methods in support of reliable epidemiological studies, radiation risk assessment, and regulatory standards for radiological protection of workers and general public." The Registries works closely with ICRP, NCRP, and Oak Ridge National Laboratory. In 1992, the National Human Radiobiology Tissue Repository (NHRTR) was established at the USTUR. The NHRTR holds biological specimens from USTUR tissue donors, as well as samples from U.S. Radium Studies acquired from Argonne National Laboratory in 1993. As part of the USTUR collaboration with the Million Person Study (MPS), radiation dose to different parts of the human heart was estimated for workers with documented intakes of ^{239}Pu or ^{226}Ra. The distribution of radionuclides, expressed in terms of concentration (Bq per kg of tissue) serves as a surrogate for radiation dose. Based on available organs from workers who donated their bodies or tissues for research, nine undissected hearts were identified: seven from USTUR Registrants with plutonium exposure (males) and two from radium workers (female and male). For the plutonium workers, estimated ^{239}Pu systemic deposition ranged from < 74 Bq to 2,272 Bq. For the radium workers, estimated ^{226}Ra systemic deposition was 10.1 MBq for the female dial painter and 14.8 kBq for the male worker. Organ dissection was based on a heart model published by Borrego et al (2019). This model includes nine cardiac substructures: aorta, left main coronary artery, left atrium, left anterior descending artery, left circumflex artery, left ventricle, right atrium, right coronary artery, and right ventricle. A total of 102 cardiac tissue samples was collected from nine cases – 78 from the seven USTUR cases and 24 from the two radium cases. Besides 81 samples from nine cardiac substructures, the following tissues were also collected: mitral (left) valve (7), tricuspid (right) valve (7), epicardial fat (6), and coronary bypass (1). In addition to tissues, blood (cardiac fluids) samples were collected for all nine workers resulting in 111 samples for radiochemical analyses. After tissue acid digestion, samples were analyzed for ^{239}Pu, ^{240}Pu, and ^{226}Ra isotopes by inductively coupled plasma mass spectrometry. These results are intended to support worker health studies by improving associated dosimetric and epidemiological models. The MPS has evaluated mortality from ischemic heart disease (IHD) for over 500,000 workers. Workers with intakes of plutonium and radium are unique in having heart tissue exposed to high-LET radiation, i.e., alpha particles. These dosimetric analyses will be generalized and incorporated into the dose-response analyses for IHD for workers at Los Alamos, Rocky Flats, Mallinckrodt and other facilities. These data are of special value to long-term space exploration where galactic cosmic rays will expose all tissues, including the heart, to high-LET radiation for long periods of time. These dose evaluations are relevant to the expanding field of theranostics that applies alpha-particle emitters in the diagnosis and treatment of tumors.

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