New Biokinetic Model Simultaneously Fits Ca-DTPA Affected and Non-Affected Urine Bioassay Data after Plutonium Contamination

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Individuals with significant internal deposition of plutonium typically undergo medical treatment with chelating agents to enhance decorporation. The trisodium salt form of calcium diethylenetriaminepentaacetate (CaDTPA) is a commonly used decorporation drug that forms stable complexes with plutonium in vivo, enhancing its excretion in urine. Since plutonium biokinetics (absorption, distribution, retention, and excretion) are strongly altered by its complexation with the chelating agent, standard models cannot be used directly to estimate the radionuclide intake. Prior to this work, only empirical descriptions and ad hoc models and approaches were available to model data affected by chelation treatment. In this study, a new model that describes plutonium biokinetics during and following chelation therapy was developed, parameterized, and validated. A USTUR whole-body donor (Case 0212) was selected for this study. This individual was exposed to plutonium as a result of an occupational wound injury and underwent extensive treatment with Ca-DTPA. Urinary excretion measurements and post-mortem plutonium activities in the liver and the skeleton were used for model development and validation, respectively. The new model (linked with the Leggett et al. Plutonium Systemic Model, the ICRP 100 Human Alimentary Tract Model, and the NCRP 156 Wound Model) was implemented in SAAM II® software. The Coordinated Network for Radiation Dosimetry (CONRAD) approach to biokinetic modeling of decorporation therapy was applied by using a chelation constant to describe the kinetics of the in vivo chelation process. The new assumptions and parameters account for both the intravenously injected Ca-DTPA and the in vivo formed Pu-DTPA chelate. The new model structure was also tested with the ICRP 67 and the Luciani and Polig Plutonium Systemic Models. The fitting of urinary excretion and autopsy data using the new model was compared to the original CONRAD Model and its optimized version, resulting in both improved goodness-of-fit to the bioassay data by order of magnitude and more accurate predictions of post-mortem plutonium retention in major depository sites.

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