Validation of Bayesian modeling approach of uncertainty in organ doses using post-mortem measurements

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The biokinetic and dosimetry models recommended by the International Commission on Radiological Protection do not incorporate dosimetric uncertainty. Recently, Bayesian approach-offering distribution of dose estimates rather than a single point value-has been applied in epidemiological risk modeling. Although the true dose is unknown, Bayesian analysis is assumed to provide information on the true dose through a posterior distribution. This study presents a unique opportunity to validate that assumption. Radiation dose is directly related to the time-dependent radionuclide activity deposited or retained in organs and tissues. Therefore, uncertainties in organ activity predictions derived from biokinetic modeling can serve as proxies for the uncertainties in dose estimation. In this study, uncertainties in model predictions of ^{239}Pu organ activities were evaluated for 20 former nuclear workers with known plutonium inhalation. Ten individuals from Los Alamos were primarily exposed to soluble Pu-nitrate, while ten from Rocky Flats were exposed to insoluble PuO_2. All individuals were volunteer tissue donors to the United States Transuranium and Uranium Registries. Urine bioassay data and post-mortem measurements of ^{239}Pu in the liver, skeleton and respiratory tract were used in the analysis. Latin hypercube sampling was employed to generate parameter sets for each realization, varying only two parameters of the human respiratory tract model: the rapidly dissolved fraction, f_r and slow dissolution rate, s_s. For each realization: (i) intake was estimated using maximum likelihood fitting of the urine bioassay data, and (ii) post-mortem organ activities, used as surrogates of true doses, were predicted based on the estimated intake. Predicted distributions of ^{239}Pu organ activities were compared to point estimates based on default parameters for soluble and insoluble plutonium, as well as to the measured post-mortem values. Results showed that in most cases, the predicted distributions did not cover the measured values (75% for liver, 90% for skeleton, and 50% for the respiratory tract), indicating a need to improve current biokinetic models. Additionally, in some cases, the model predictions were not conservative, which raises concerns from a radiation protection standpoint.

USTUR-0678-24