NCRP Commentary No. 31:
Development of Kinetic and Anatomical Models for Brain Dosimetry for Internally Deposited Radionuclides

National Council on Radiation Protection and Measurements

NCRP Commentary No. 31, *Development of Kinetic and Anatomical Models for Brain Dosimetry for Internally Deposited Radionuclides*, examines ways to improve current biokinetic and dosimetric modeling of the brain that may result in improved dose estimates for brain tissue from internally deposited radionuclides, with emphasis on alpha emitters.

In addition to exploring improvements in brain dosimetry relevant to radiation protection, better estimates of brain radiation doses from alpha emitters will be applicable to ongoing epidemiologic research aimed at evaluating dementia, Alzheimer's, Parkinson's, motor neuron diseases, and cognitive impairment as possible adverse effects of radionuclide depositions in the brain.

Explores improved biokinetic and dosimetric models of brain dose from internally deposited radionuclides, especially alpha emitters.

- Case studies were performed for 18 selected radioisotopes.
- Estimates for brain dose were improved by explicitly modeling brain kinetics.

New methods improve dose estimates to the brain.

- The brain typically has a much lower rate of uptake but a longer residence time than do most other studied soft tissues.
- Owing to a longer residence time, an initially low uptake of a radionuclide by the brain does not indicate that brain dose is substantially lower than most other tissues.

Improved models will better estimate brain radiation dose and will help radiation protection and brain disease research.
Relevant brain disease research includes Alzheimer's, Parkinson's, motor neuron diseases, and cognitive impairment as possible adverse effects of radionuclide depositions in the brain.

As a matter of practice, element- or compound-specific biokinetic models are used to derive dose coefficients for radionuclides or reconstruct doses to tissues from internal emitters. Generally, a systemic model for an element explicitly depicts only the element's primary repositories.

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Remaining tissues are aggregated into a source region called "*Other*" in which the element is assumed to be uniformly distributed. In systemic models used in radiation protection, the brain usually is addressed as an implicit mass fraction of *Other* rather than an explicitly depicted repository.

For this Commentary, case studies were performed for selected radioisotopes of 10 elements (manganese, cesium, mercury, bismuth, lead, polonium, radium, uranium, plutonium, and americium) to investigate the extent to which dose estimates for brain tissue might be improved for internal emitters by explicitly modeling brain kinetics rather than treating the brain as a mass fraction of *Other*. In all, 18 radionuclides were addressed. Injection dose coefficients were calculated for each radionuclide using two versions of the International Commission on Radiological Protection's (ICRP) current systemic biokinetic model for that element: the original version and a modified version differing only in the treatment of brain. If the ICRP model for the element contained an explicit brain region, the modified version of that model depicted brain instead as a mass fraction of Other. If the ICRP model included brain in *Other*, the modified version included an explicit brain region with kinetics based on best available brain-specific data. The comparison of dose coefficients for a given radionuclide was expressed as a ratio A:B, where A and B are the dose coefficients based on the versions of the model with and without an explicit brain region, respectively.

For the 18 radionuclides addressed in this study, the ratio A:B ranged from 0.13 to 4.8. The results indicate that addition of an explicitly identified brain can sometimes result in a substantial (factor of 5 or more) difference in the dose coefficient for the brain compared with use of an implicit brain model. In such cases it is important to incorporate an explicit brain region into the systemic model used for dose reconstruction, if feasible in view of the quality and quantity of available biokinetic data for the element of interest.

An important finding from these case studies and additional reviews of the literature is that the brain typically has a much lower rate of uptake per gram of tissue but a longer residence time than do most other studied soft tissues. Thus, an initially low uptake of a radionuclide by brain should not be interpreted as indicating that the dose to brain is substantially lower than that to most other tissues.

In recent years there has been a considerable expansion of information on the anatomy and functions of the brain. The recent advances in MRI technology have enabled measurements of brain function linked to brain structure. It may now be feasible to refine ICRP's current dosimetric methodology for the brain to produce a relatively detailed brain model having a more realistic spatial configuration.