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Brain Dosimetry for Internally Deposited Radionuclides

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OAK RIDGE National Laboratory

National Council on Radiation Protection and Measurements

VANDERBILT UNIVERSITY

College of Pharmacy and Pharmaceutical Sciences
WASHINGTON STATE UNIVERSITY

ICRP's Biokinetic Treatment of Systemic (Absorbed) Radionuclides

- Systemic biokinetic models generally are element specific
- Typically, the systemic biokinetic model for an element *explicitly* depicts only a small number of dosimetrically important tissues
- Remaining tissues and fluids are aggregated into a pool called *Other tissue*
- Activity in *Other tissue* is assumed to be uniformly distributed

ICRP Treatment of Brain for Internal Emitters

- Typically, brain is included in *Other tissue* because it is rarely a major repository for a radionuclide
- Brain is addressed *explicitly* in systemic biokinetic models for a few elements with elevated uptake by brain:
  - ✓ Nitrogen as ammonia (ICRP Publication 53)
  - ✓ Copper (ICRP Publication 30)
  - ✓ Manganese (ICRP OIR series)
  - ✓ Mercury (ICRP OIR series)

Growing Interest in Brain Dosimetry for Internal Emitters

- U.S. Million Person Study: estimating brain doses and evaluating dementia, Alzheimer's, and other motor neuron diseases as possible adverse effects of radionuclide depositions in the brain
- National Aeronautics and Space Administration: interested in adverse effects of alpha dose on brain as a limited but perhaps informative analogy of behavioral and cognitive effects of galactic cosmic ray (high Z and high energy ions) exposure on astronauts

NCRP Scientific Committee 6-12

Development of Models for Brain Dosimetry for Internally Deposited Radionuclides (2018 – 2020):

- Richard Leggett (*Chair*, ORNL)
- Sergei Tolmachev (*Vice-chair*, USTUR)
- Maia Avtandilashvili (USTUR)
- Keith Eckerman (ORNL, *retired*)
- George Sgouros (Johns Hopkins University)
- Gayle Woloschak (Northwestern University)
- Helen Grogan (*Staff Consultant,* Cascade Scientific)

Purpose of This Study

To investigate potential improvements in brain dose estimates for internal emitters resulting from *explicit* rather than *implicit* biokinetic treatment of brain (and improved dosimetric treatment)

- *Explicit treatment:* systemic biokinetic model contains compartments and transfer rates specifically representing brain kinetics
- *Implicit treatment*: brain is considered as part of *Other tissue*

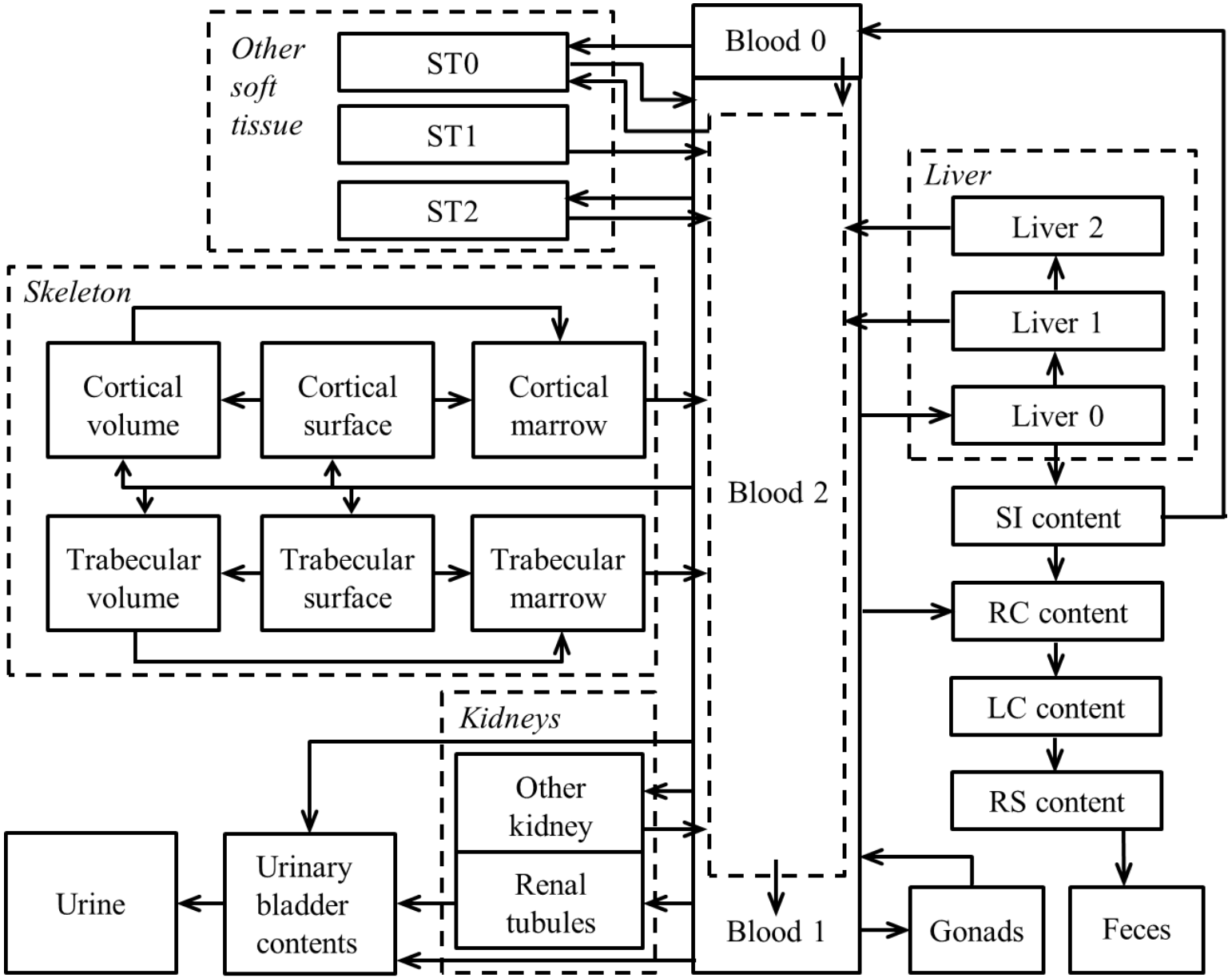
Study Design

- Several elements (Mn, Cs, Hg, Bi, Pb, Po, U, Pu, Am), for which brain kinetics can be modeled reasonably well, were selected
- For a selected radioisotope of each element, we compared two derived injection dose coefficients (Sv Bq^{-1}) for brain, using ICRP Publication 133 (2016) dosimetry and two versions of the latest ICRP systemic model for occupational intake of the radionuclide:
  1. with brain contained implicitly in *Other tissue*
  2. with brain explicitly modeled

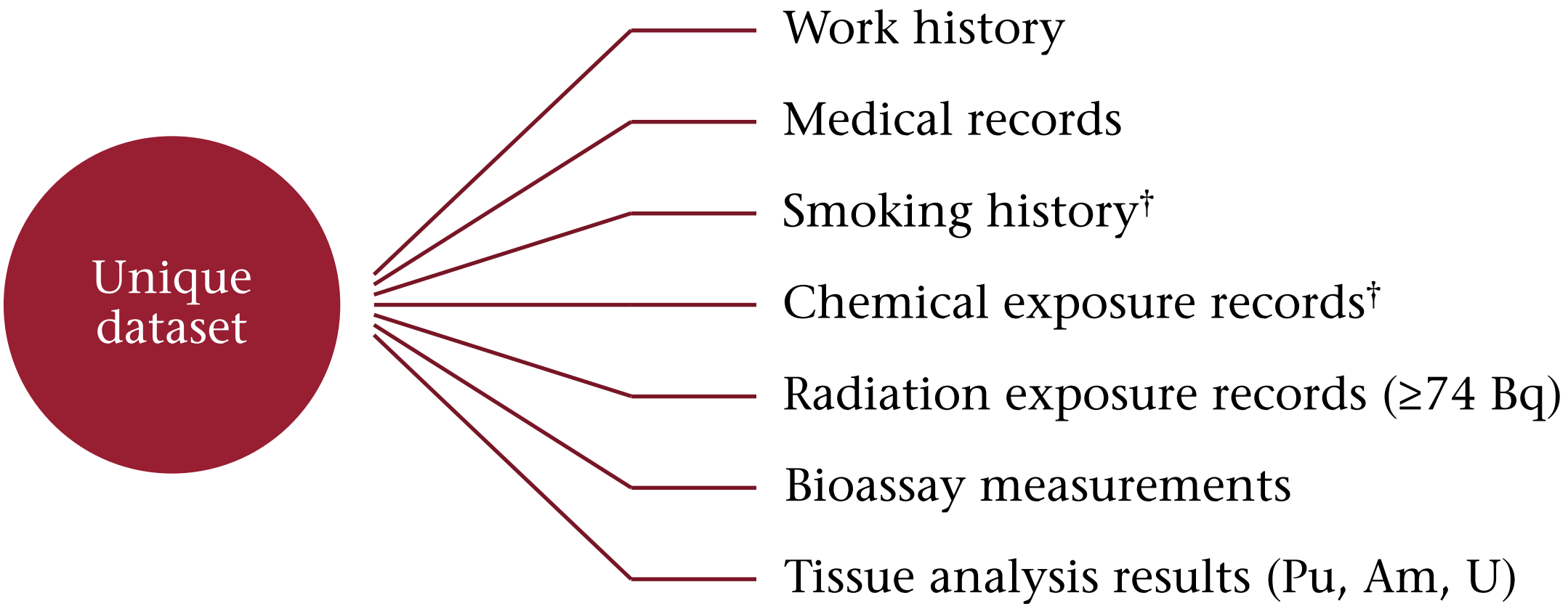
Plutonium-239

- The ICRP's biokinetic model for systemic plutonium is ICRP Publication 141 (2019)
- As in previous ICRP models for plutonium, brain is included implicitly in *Other tissue*
- In the plutonium model, *Other tissue* consists of three compartments representing fast, moderate, and slow removal of plutonium back to blood

ICRP 141 Biokinetic Model for Systemic Plutonium

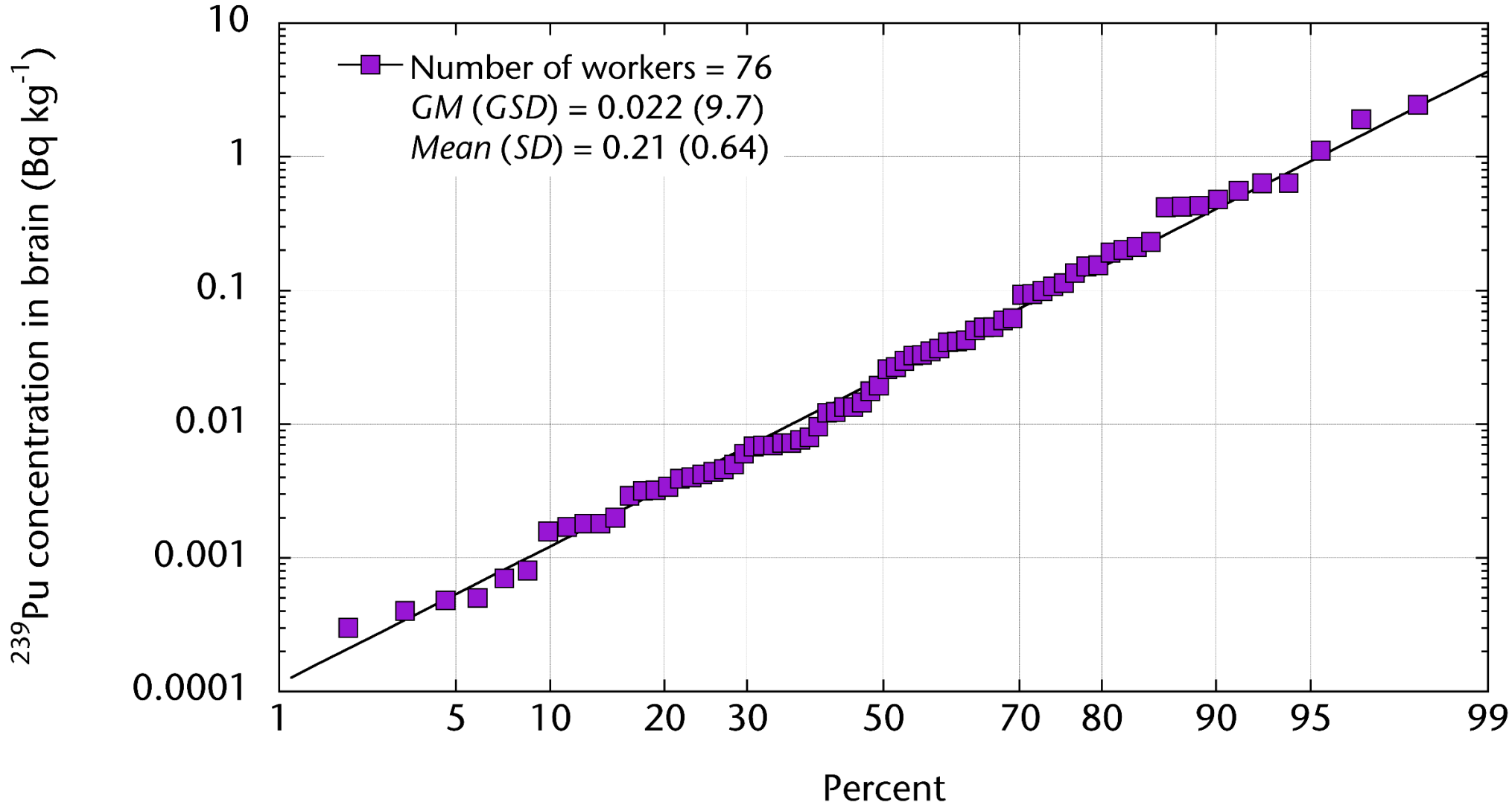


US Transuranium and Uranium Registries (USTUR)



† - self-reported data

USTUR: Plutonium in Brain of Occupationally Exposed Individuals



Plutonium Accumulation in Brain

Fraction of systemic activity: $f = A(\text{Brain})/A(\text{Systemic})$

- Data from dogs indicate a central tendency of

  $f \sim 0.0013$ at 2 – 4 weeks post intravenous injection

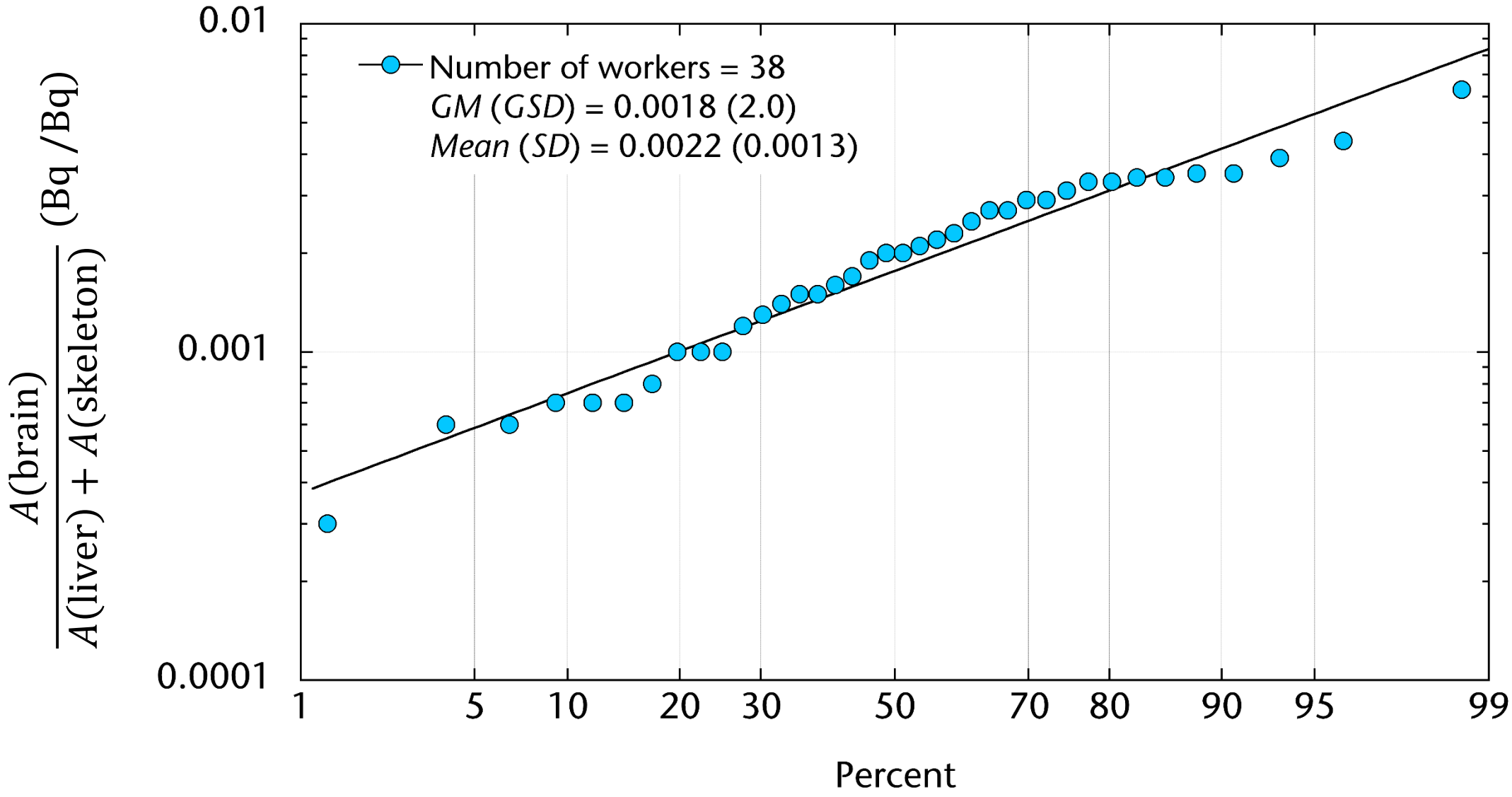
- Mayak PA data for plutonium workers indicate a central tendency of

  $f \sim 0.002$ (0.0010 – 0.0032) at 4 – 44 years post intake

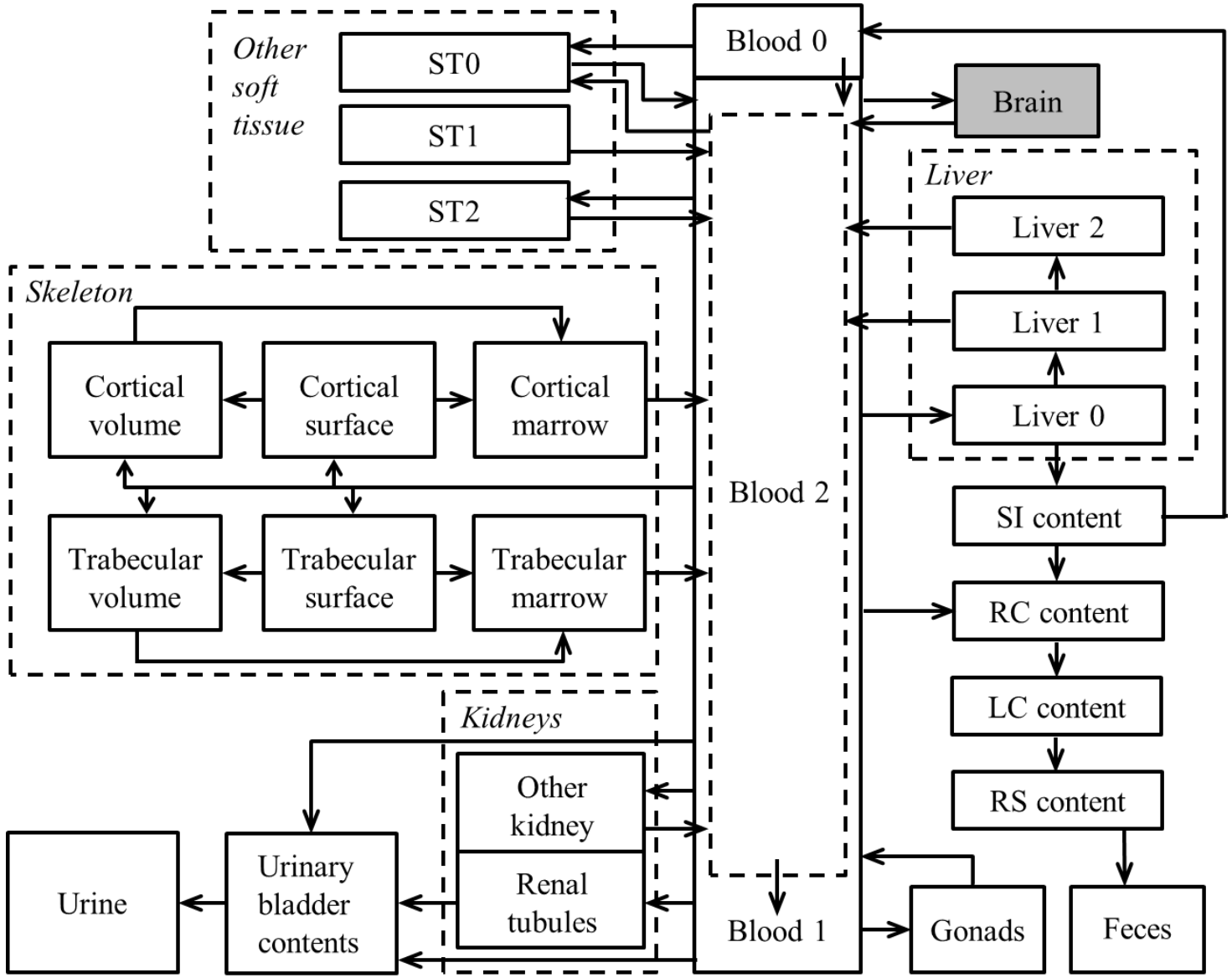
- USTUR data for plutonium workers indicate a central tendency of

  $f \sim 0.002$ (0.0003 – 0.0063) at 18 – 64 years post intake

Plutonium: How Much is in the Brain?



Alternate Biokinetic Model for Systemic Plutonium with Explicitly Depicted Brain



Dose Coefficient (Sv Bq^{-1}) for Brain

Nuclide	Biokinetic model with		Ratio B:A
	Implicit brain (A)	*Explicit* brain (B)	
Americium-241	2.80×10^{-5}	3.62×10^{-6}	0.13
Bismuth-207	2.20×10^{-9}	1.25×10^{-9}	0.57
Uranium-234	1.38×10^{-6}	1.11×10^{-6}	0.80
Plutonium-239	2.56×10^{-5}	2.45×10^{-5}	0.96
Mercury-203 (vapor)	5.25×10^{-10}	7.32×10^{-10}	1.39
Cesium-134	5.22×10^{-9}	7.63×10^{-9}	1.46
Manganese-54	1.39×10^{-9}	2.41×10^{-9}	1.73
Radium-226	1.87×10^{-7}	3.62×10^{-7}	1.94
Polonium-210	3.12×10^{-7}	6.20×10^{-7}	1.99
Lead-210	1.37×10^{-7}	4.85×10^{-7}	3.54

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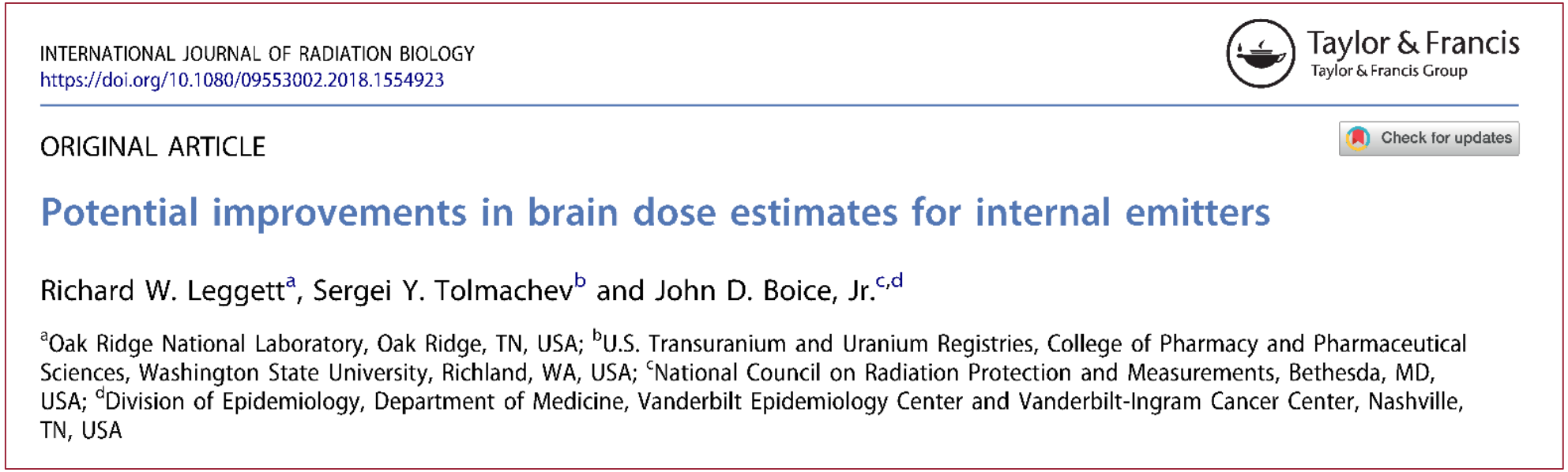
Conclusions

- Where feasible, the brain should be depicted explicitly in biokinetic models used in epidemiological studies addressing adverse effects of ionizing radiation



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ORIGINAL ARTICLE

Potential improvements in brain dose estimates for internal emitters

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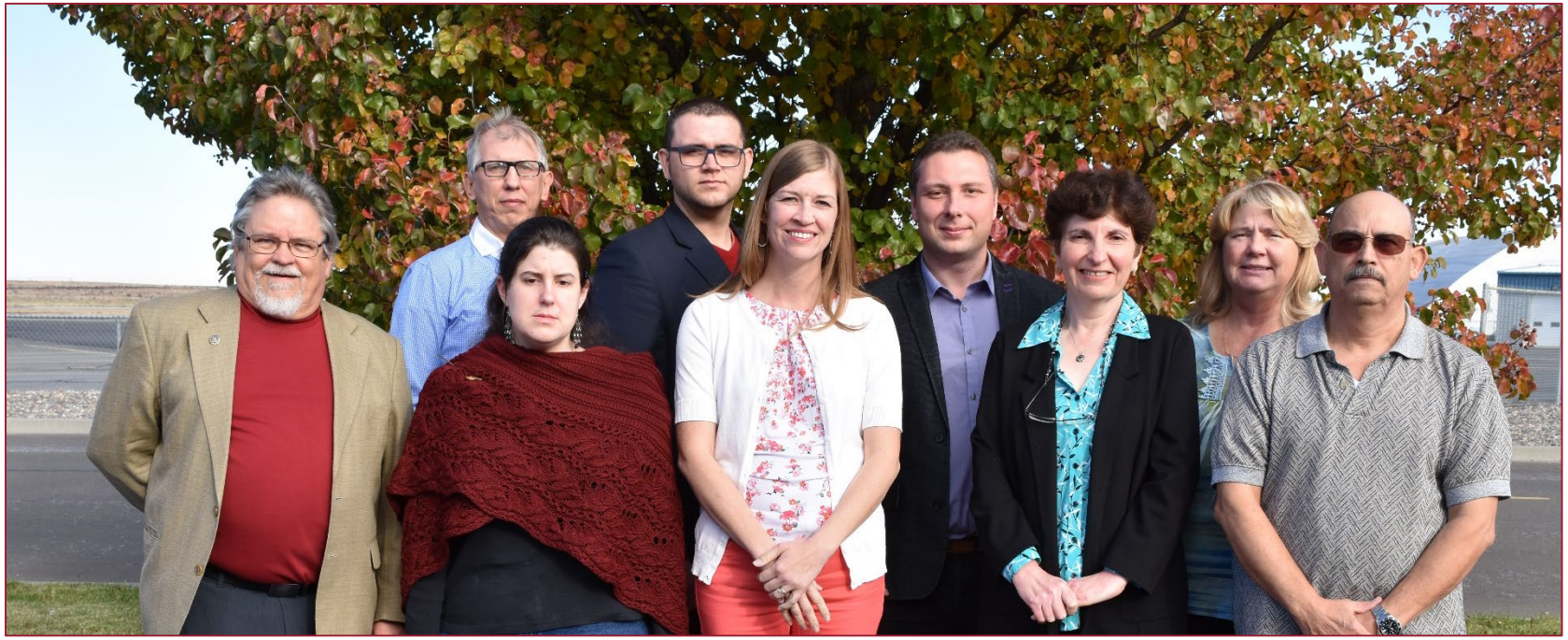
Leggett RW, Tolmachev SY, Boice JD. Potential improvements in brain dose estimates for internal emitters. International Journal of Radiation Biology: 1-13; 2018 (e-pub)

Acknowledgment



Questions?

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