



First Annual Workshop – “A Fresh Perspective”

2021 HPS Midyear Workshop

# Uncertainty Analysis on Organ Activities and Intakes from Occupational Exposure to Plutonium

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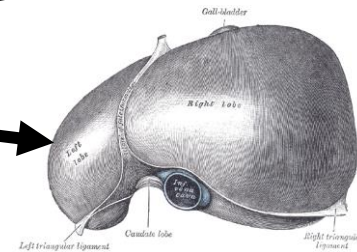
# Motivation

- In radiation epidemiology, worksite records and bioassay measurements are used to estimate the radiation doses
- Bioassay data are typically collected by worksite and may not be available after the end of employment
- Post-mortem tissue/organ analyses can be used to evaluate the accuracy of the reference biokinetic and dosimetric models used for radiation epidemiology



# Objectives

- Comparison of plutonium activity in *liver +skeleton* predicted from *urine bioassay* collected *during* and/or *after employment* with *post-mortem* radiochemical analyses to evaluate biokinetic models
- Comparison of intakes (as dose surrogates) predicted using *urine bioassay* to those predicted using both *urine bioassay* and *post-mortem tissue analysis results*



Bioassay Monitoring at Los Alamos: *A Guide for workers and their families.*

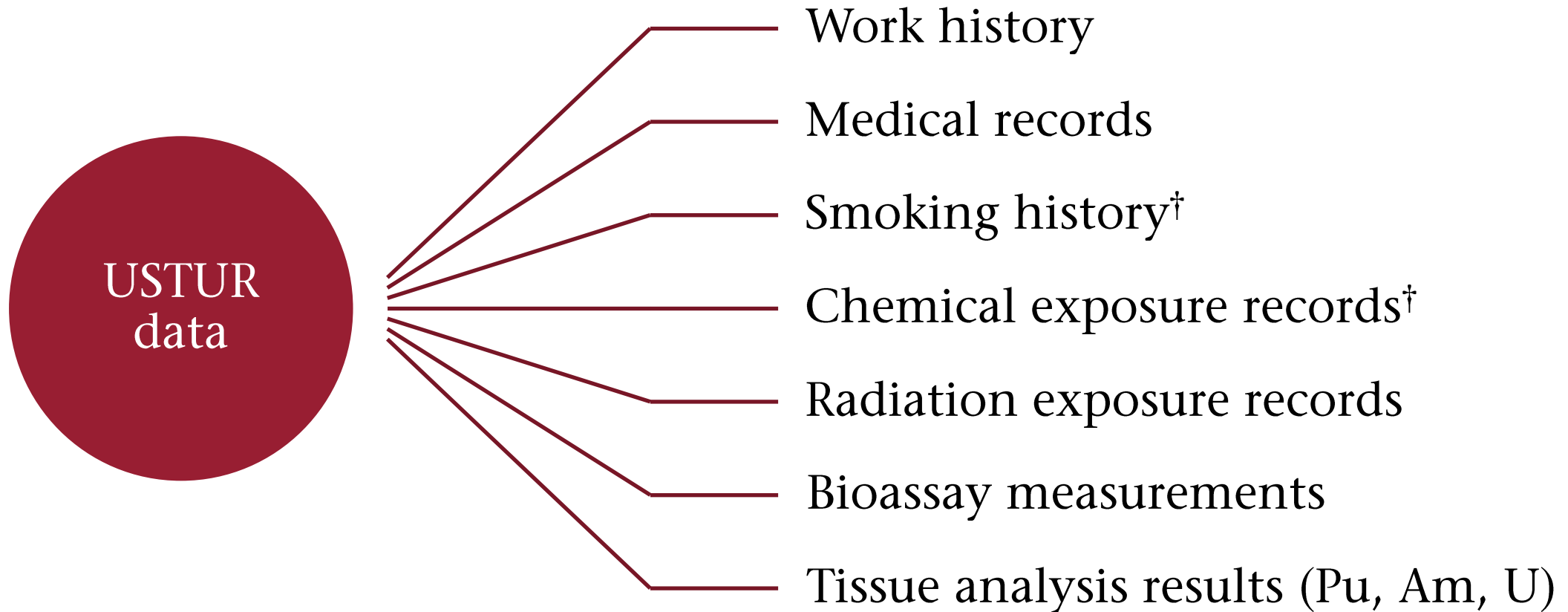
Henry Gray. *Anatomy of the Human Body*; <https://www.turbosquid.com/3d-models/3d-human-female-skeleton-pose/1025026>





# Unique Data Resource

- Registrant acceptance:  $\geq 74$  Bq (2 nCi) systemic content

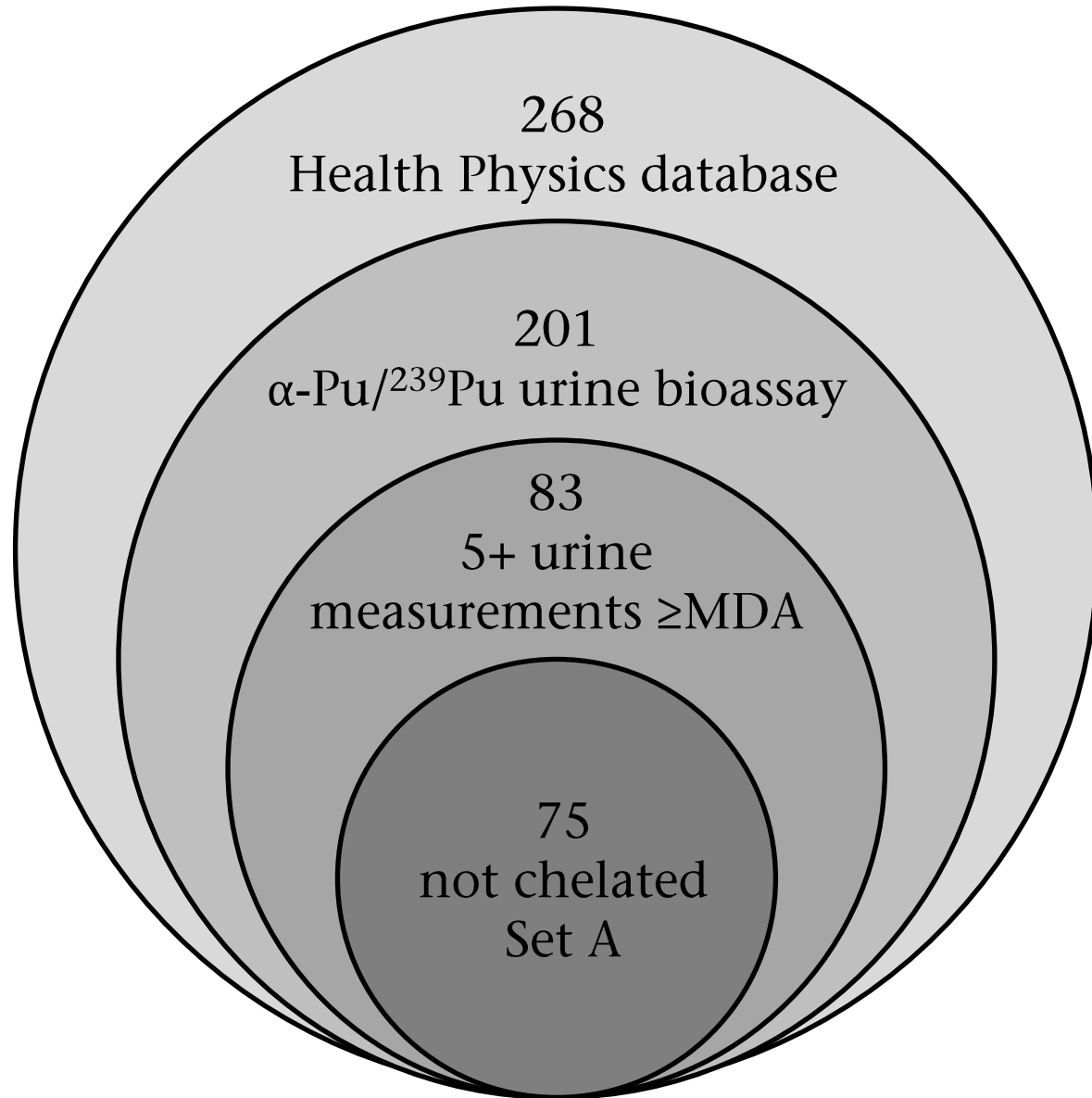


<sup>†</sup> - self-reported data

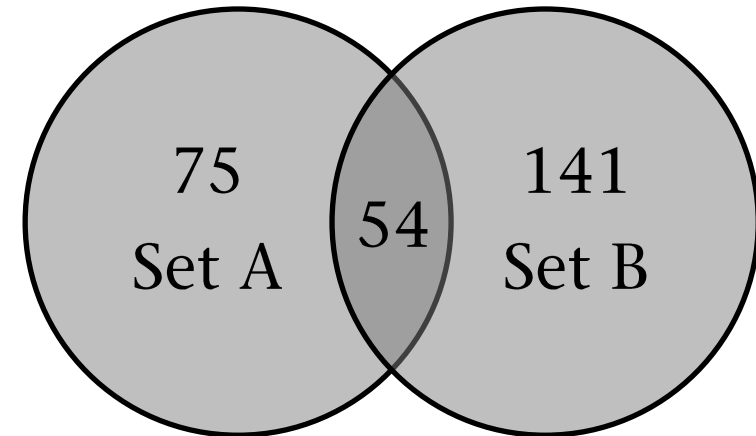
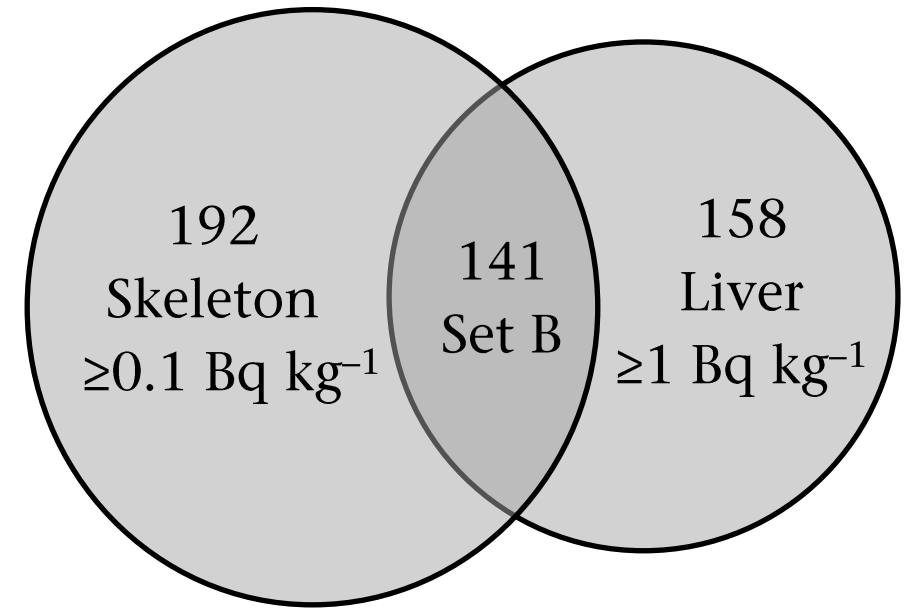




# Study Case Selection Criteria



## Radiochemical analysis





# Studied Group – “You Pee Pu” (UPPU)

- Total of 26 individuals, 14 are USTUR Registrants
- Worksite: Los Alamos Scientific Laboratory
- Exposure period: 1944–1948 (Manhattan Project)
- Post-exposure follow-up: 1953–1997
- Studied cases: 11 (7 whole-body, 4 partial-body)
- Route of intake: chronic inhalation,  $0.3 \mu\text{m}$  (AMAD)
- Material: 78%  $\text{Pu}(\text{NO}_3)_4$ , 22% refractory  $\text{PuO}_2$ <sup>†</sup>
- Post-mortem organ activity:
  - Liver: 27.8–927 Bq
  - Skeleton: 48.6–897 Bq



Open hood in D-Building–1944

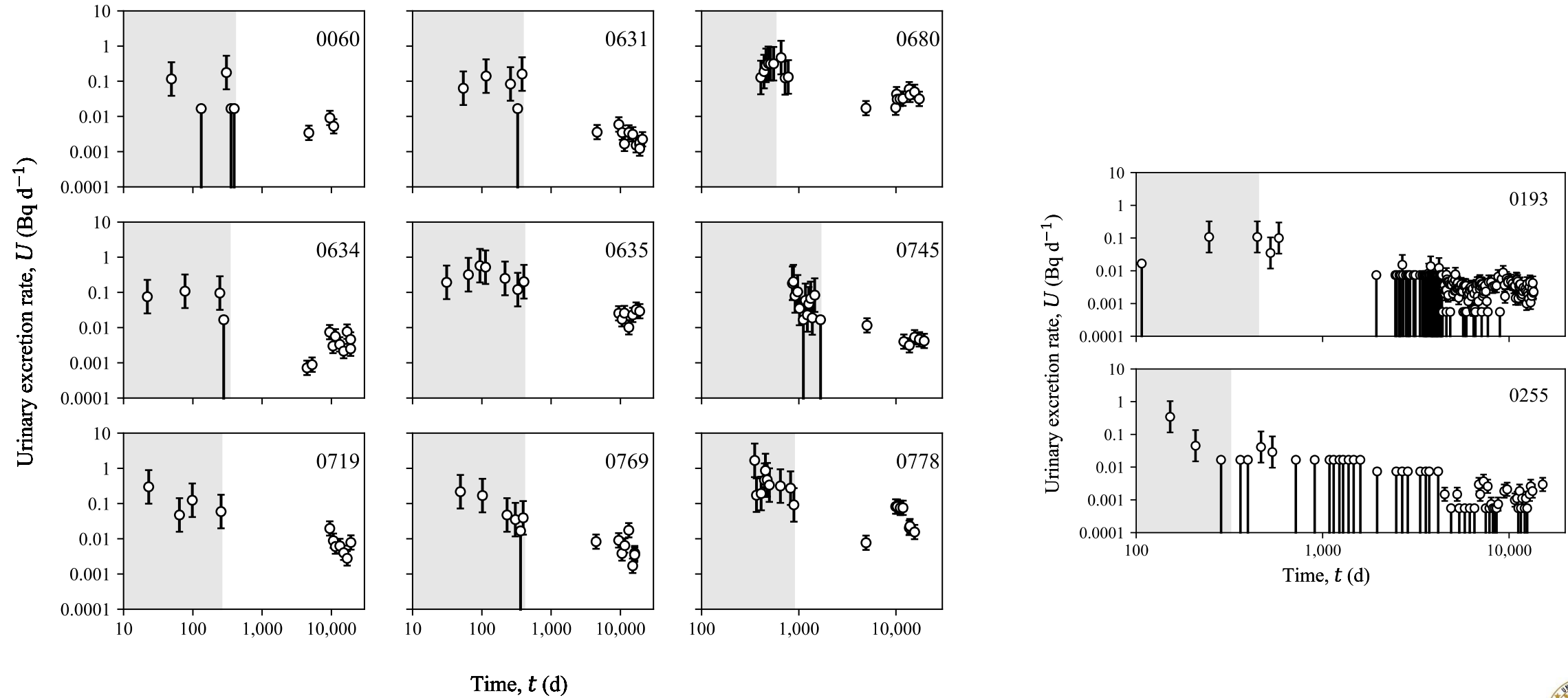
Los Alamos Science, Vol 23, 1995

<sup>†</sup> - Šefl M et al. *Inhalation of Soluble Plutonium: 53-year Follow-up of Manhattan Project Worker*. Health Phys. 120(6): 661–670; 2021.





# Data: Urine Bioassay for Study Cases





# Data: Post-mortem Organ Activities

- Organ activity (Bq) = Concentration (Bq/kg) × Weight (kg)
- Liver: concentration and weight measured
- Skeleton: concentration and weight estimated or measured

Skeleton	Activity concentration based on analysis of	Weight
Whole body	70–90 bone samples (right side of the skeleton)	Measured
Partial body	4–8 bone samples	Estimated*

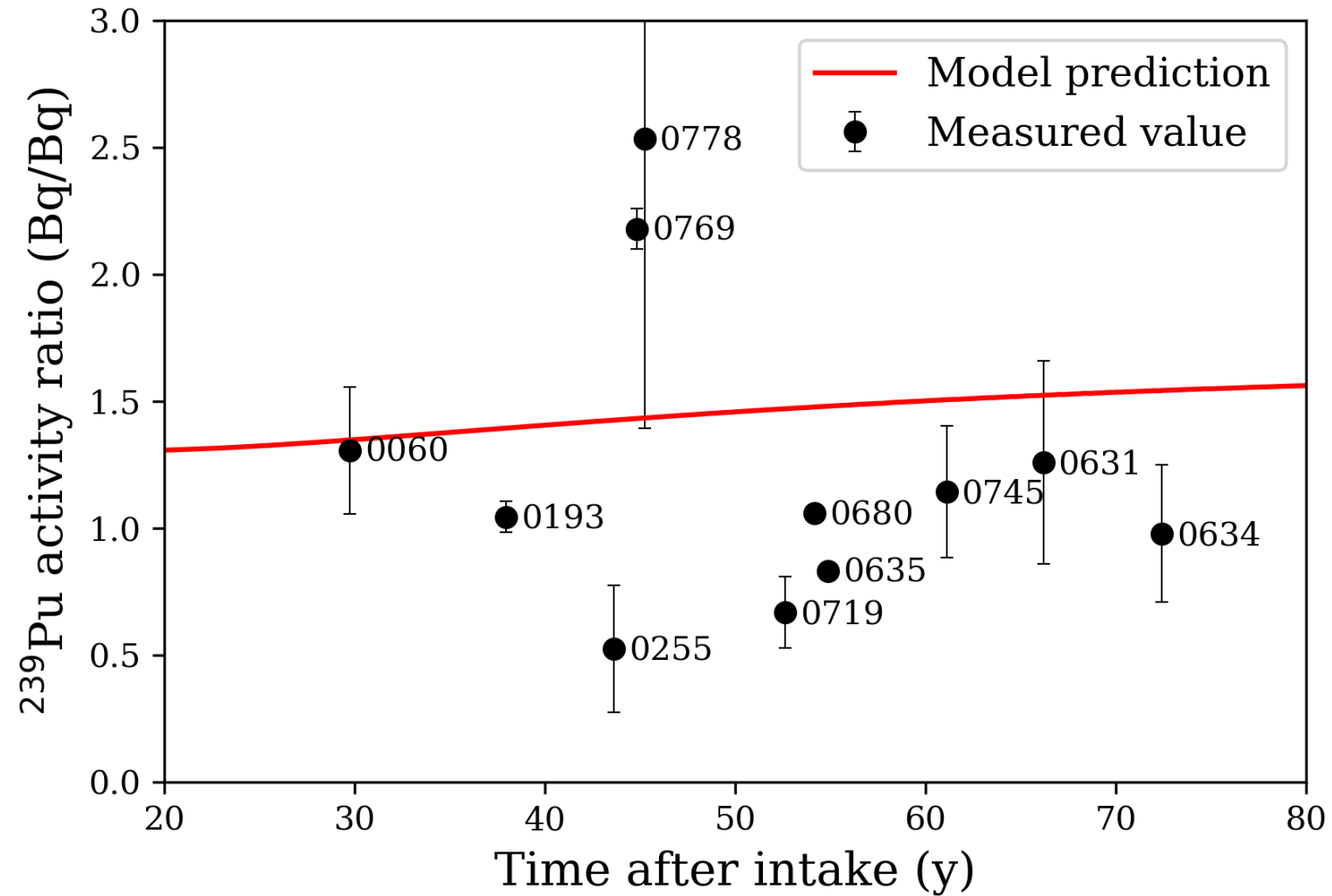
\*Avtandilashvili M, Tolmachev SY. *Modeling the Skeleton Weight of an Adult Caucasian Man. Health Phys.* 117(2):149–155; 2019.







# Skeleton-to-Liver Activity Ratio



Predicted using IMBA Professional Plus®: ICRP Publication 130 Human Respiratory Tract Model, ICRP Publication 141 Plutonium Systemic Model, ICRP Publication 30 Gastrointestinal Tract Model





# Bias in Organ Activity

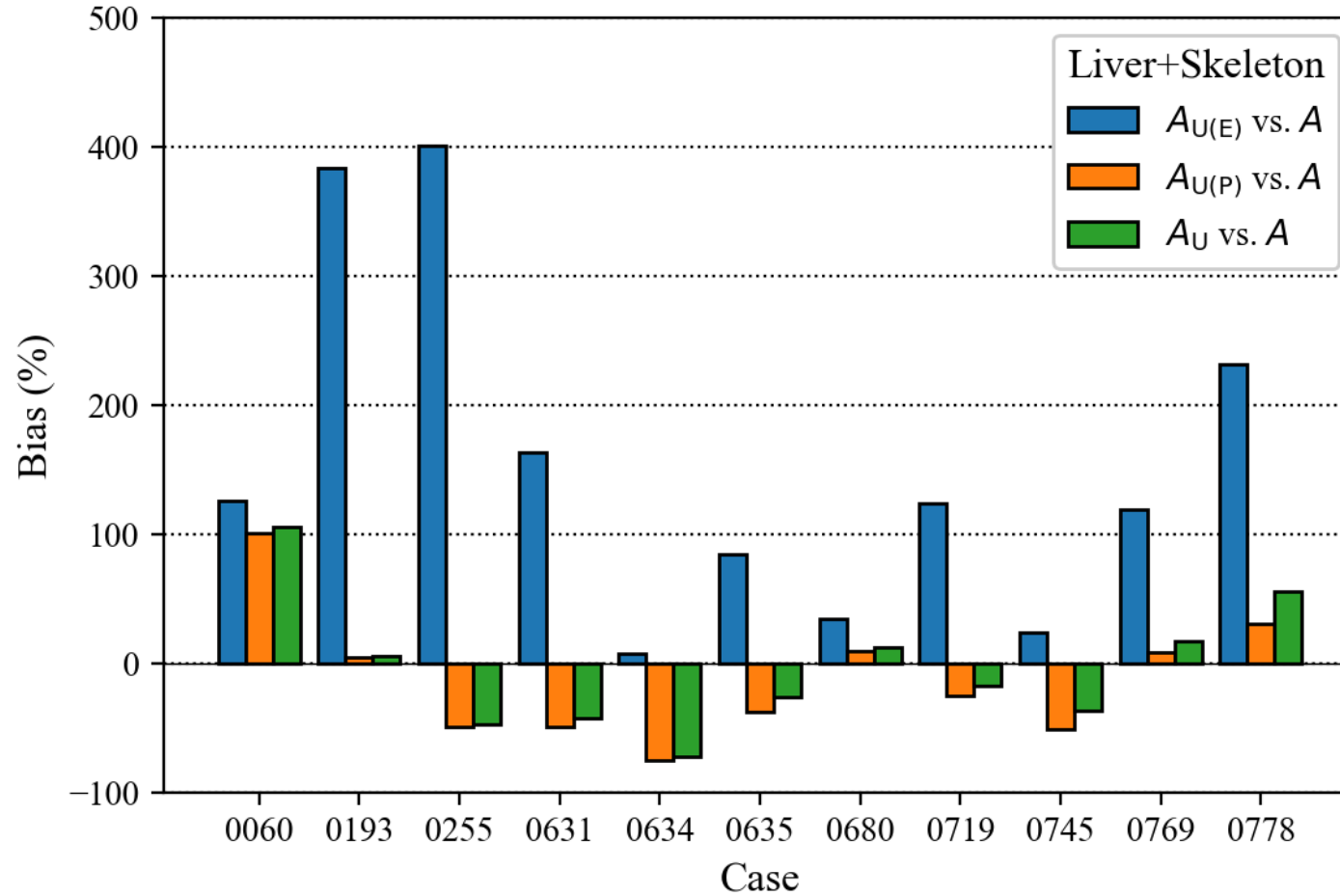
- IMBA Professional Plus fit of *urine bioassay* to estimate intake
- Predict plutonium activities  $A_{U(E)/U(P)/U}$  (Bq) in liver+skeleton (to eliminate intersubject liver and skeleton variability) at the time of death
- Compare to *measured* post-mortem liver+skeleton activity  $A$  with *predicted* value based on:
  - urine data collected during *exposure* period,  $A_{U(E)}$
  - using urine data collected *post-exposure*,  $A_{U(P)}$
  - using *all* available urine data,  $A_U$

$$\text{Bias}(\%) = \frac{A_U - A}{A} \times 100$$





# Bias in Liver+Skeleton Activity



## Mean absolute bias (%)

$A_{U(E)}$ vs. $A$	$156 \pm 133$
$A_{U(P)}$ vs. $A$	$40 \pm 29$
$A_U$ vs. $A$	$40 \pm 30$





# Bias in Intakes

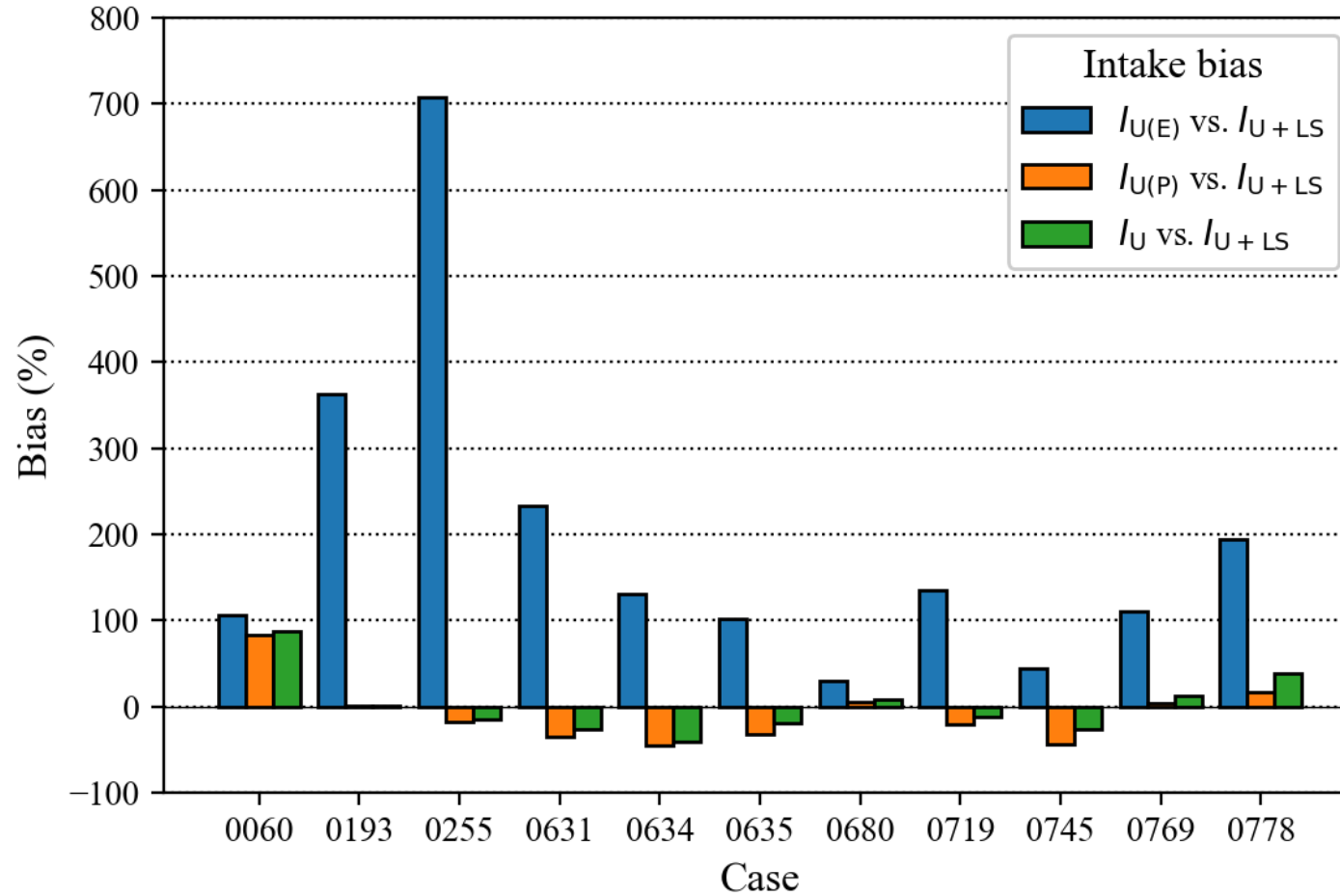
- Intakes are a surrogate for committed equivalent/effective doses
- Reference “best estimate” using all available data, urine bioassay and post-mortem liver+skeleton activity –  $I_{U+LS}$
- $I_{U(E)}$  – using urine data collected during *exposure* period
- $I_{U(P)}$  – using urine data collected *post-exposure*
- $I_U$  – using *all* available urine data

$$\text{Bias}(\%) = \frac{I_U - I_{U+LS}}{I_{U+LS}} \times 100$$





# Bias in Intakes



## Mean absolute bias (%)

$I_{U(E)}$ vs. $I_{U+LS}$	196±193
$I_{U(P)}$ vs. $I_{U+LS}$	28±24
$I_U$ vs. $I_{U+LS}$	26±24





# Conclusions

For this study group:

- On average, using only urine data collected during exposure period overestimated the plutonium liver+skeleton (systemic) activity by factor of 2.6 and intakes by a factor of almost 3
  - Number and quality of the early urine measurements
  - Uncertainty of the intake scenario (time)
- Using all urine data including post-exposure follow-up measurements significantly improved the activity/intake estimates
  - The estimate was driven by post-exposure follow-up data





Thank you!

