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Bias in Predicted Plutonium Organ Activities for Manhattan Project Workers

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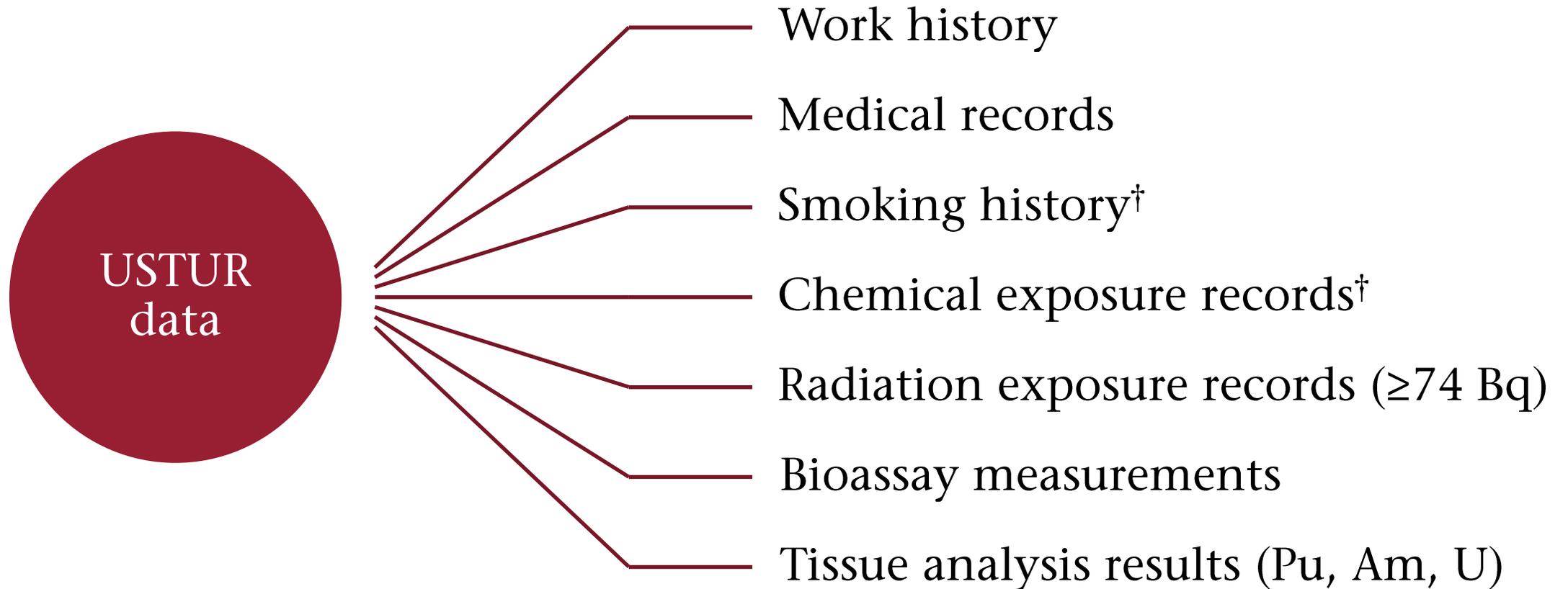www.ustur.wsu.edu

Motivation

- In radiation epidemiology, worksite records and bioassay measurements are used to estimate the organ 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
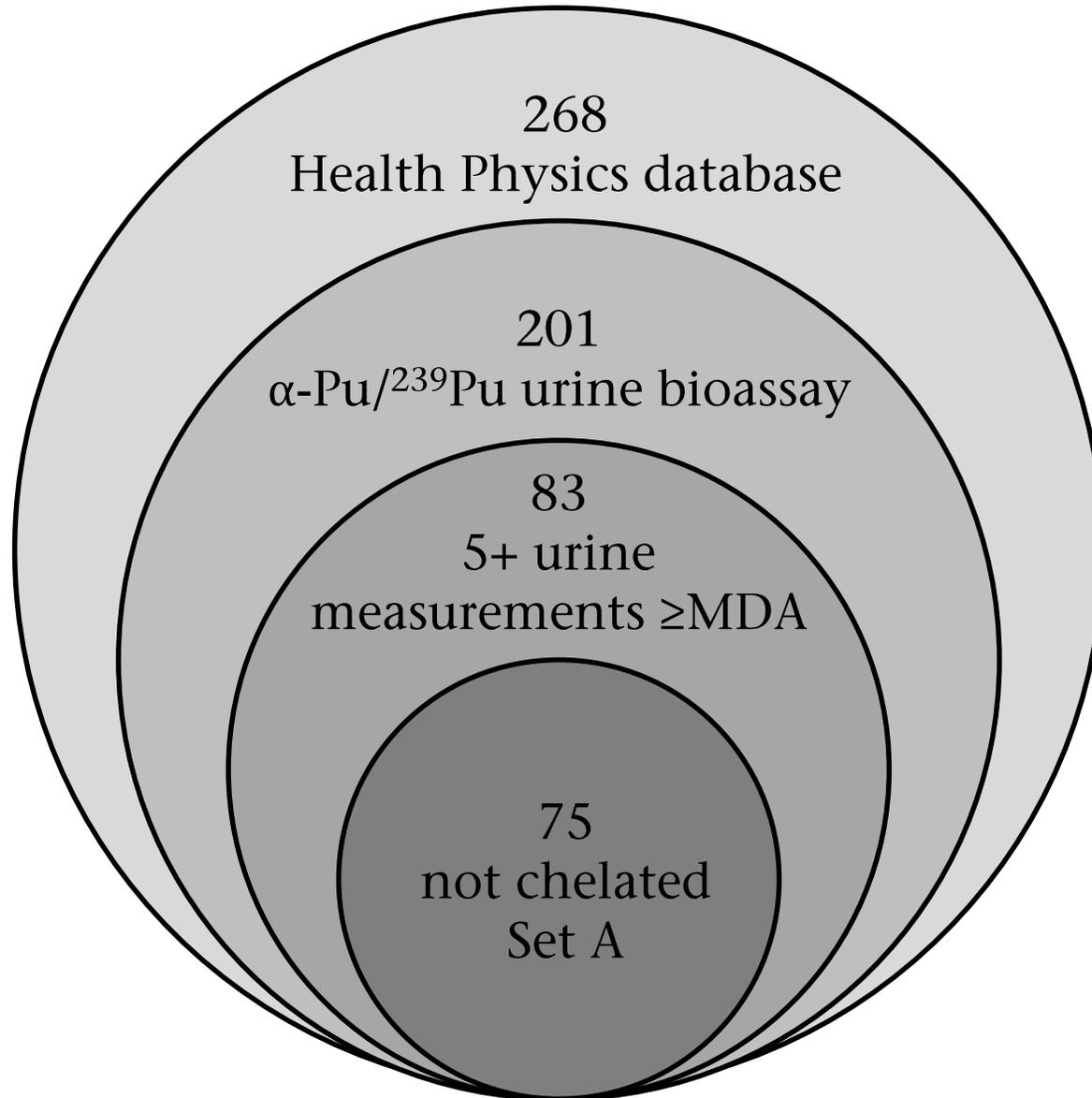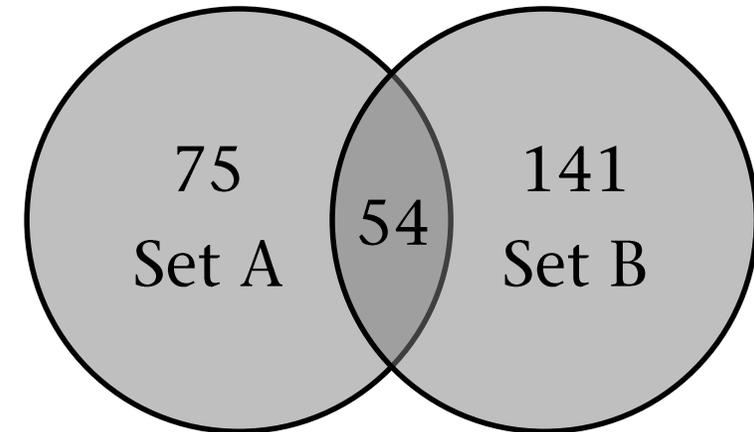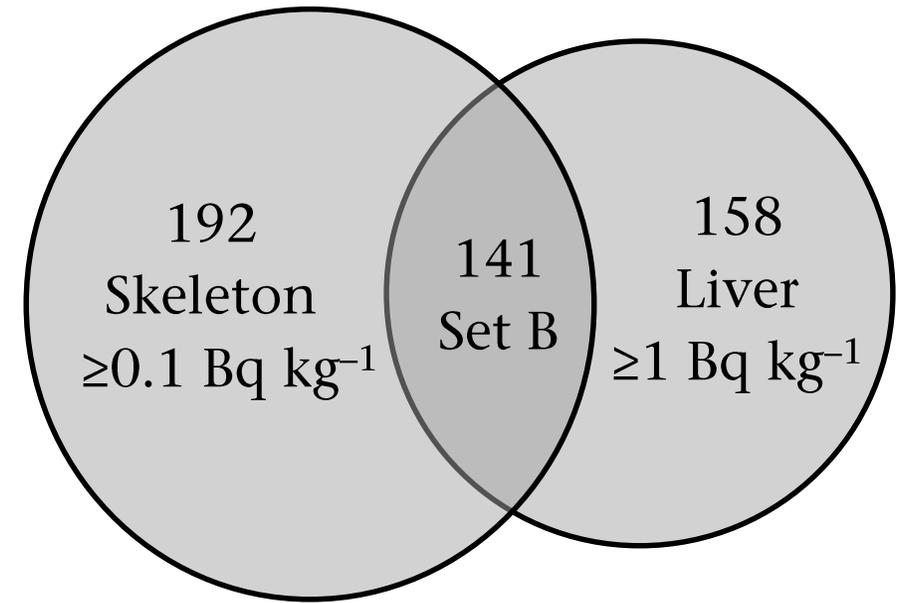
Unique Data Resource

USTUR data

- Work history
- Medical records
- Smoking history†
- Chemical exposure records†
- Radiation exposure records (≥74 Bq)
- Bioassay measurements
- Tissue analysis results (Pu, Am, U)

† - self-reported data

Case Selection Criteria

268
Health Physics database

201
α-Pu/^{239}Pu urine bioassay

83
5+ urine
measurements ≥MDA

75
not chelated
Set A

Radiochemical analysis

192
Skeleton
≥0.1 Bq kg^{-1}

141
Set B

158
Liver
≥1 Bq kg^{-1}

75
Set A

54

141
Set B

Studied Group – "You Pee Pu" (UPPU)

- Worksite: Los Alamos Scientific Laboratory
- Exposure period: 1944–1948 (Manhattan Project)
- Post-exposure follow-up: 1953–1997
- Studied cases: 7 whole-body, 4 partial-body
- Route of intake: chronic inhalation, 0.3 µm (AMAD)
- Material: 78% $Pu(NO_3)_4$, 22% refractory PuO_2
- Post-mortem organ activity:
  - Liver: 27.8–927 Bq
  - Skeleton: 48.6–897 Bq

Objective

- Comparison of plutonium activity in *liver* and *skeleton* predicted from *urine bioassay* collected *during* and/or *after* employment with *post-mortem* radiochemical analyses
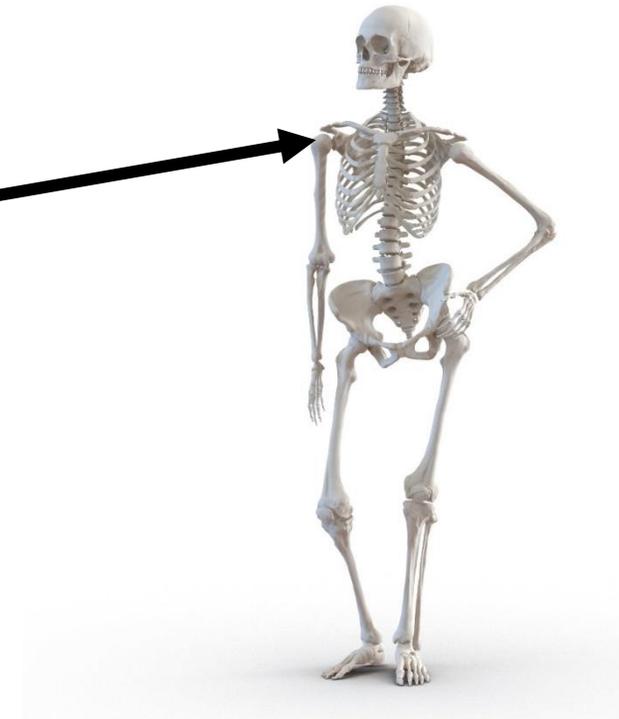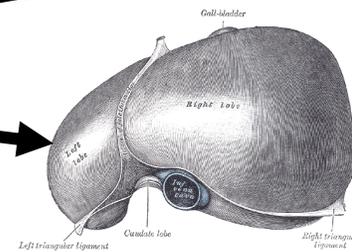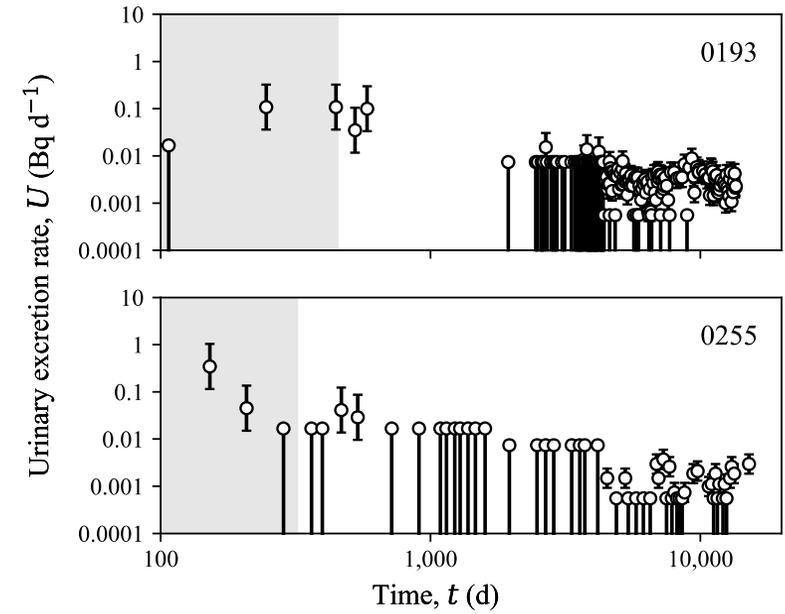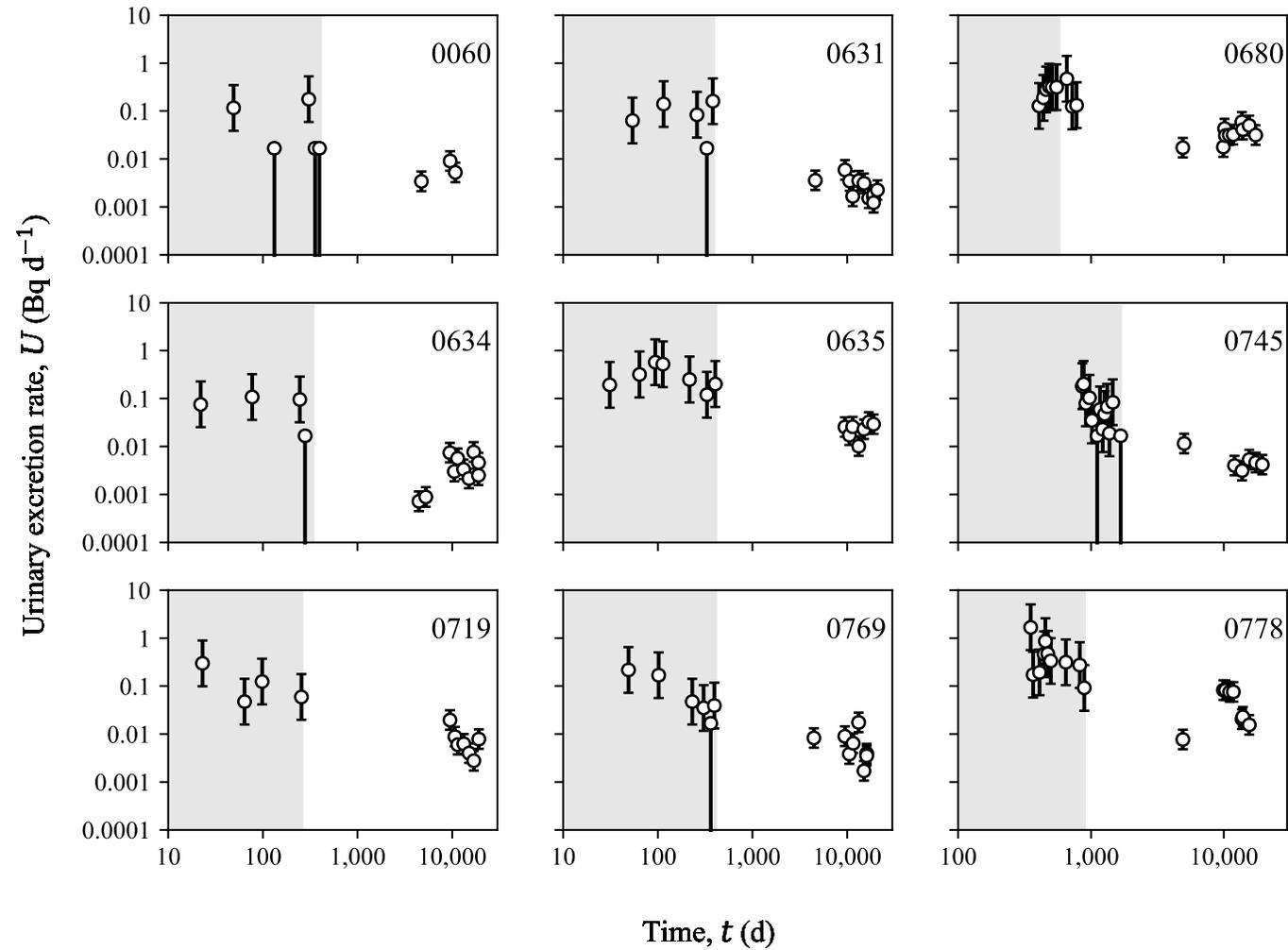

Bioassay Monitoring at Los Alamos: *A Guide for workers and their families.*

Henry Gray. *Anatomy of the Human Body*

https://www.turbosquid.com/3d-models/3d-human-female-skeleton-pose/1025026

Urine bioassay

Post-mortem organ activity estimation

- 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.

Bias in Organ Activity

- IMBA Professional Plus fit of *urine bioassay* to estimate intake

- Predict plutonium activities $A_{\mathrm{E/P/U}}$ (Bq) in liver and skeleton at the time of death

- Compare to *measured* post-mortem organ activities A_{M}

- A_{E} – using urine data collected during *exposure* period

- A_{P} – using urine data collected *post-exposure*

- A_{U} – using *all* available urine data

$$\mathrm{Bias}(\%) = \frac{A_{\mathrm{E/P/U}} - A_{\mathrm{M}}}{A_{\mathrm{M}}} \times 100$$

Bias in Liver and Skeleton Activity
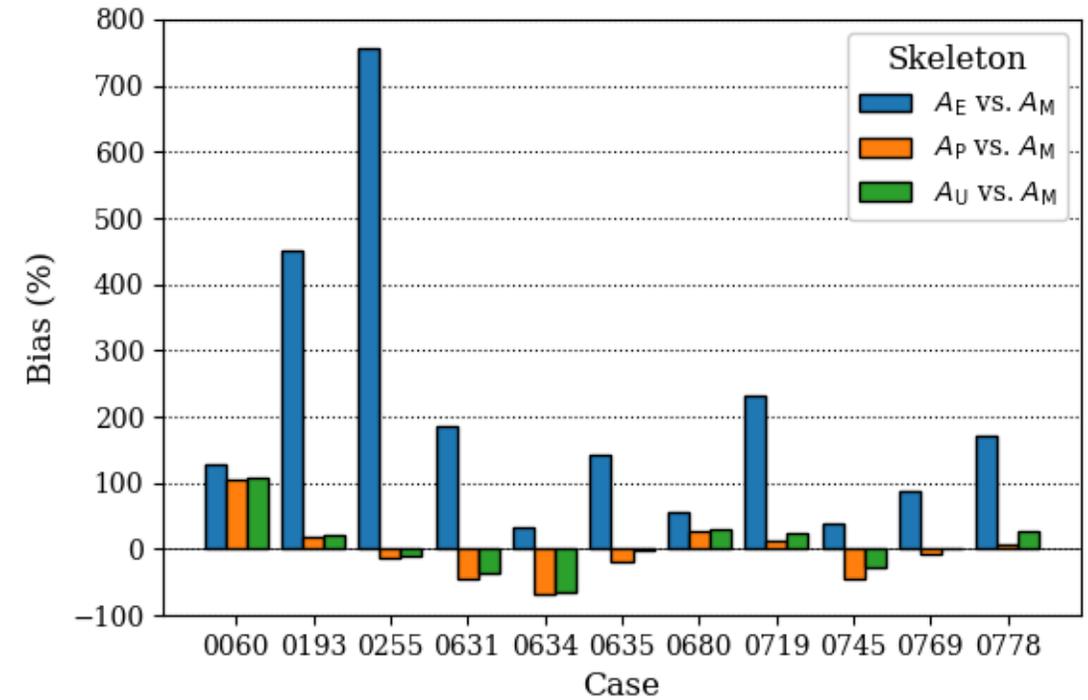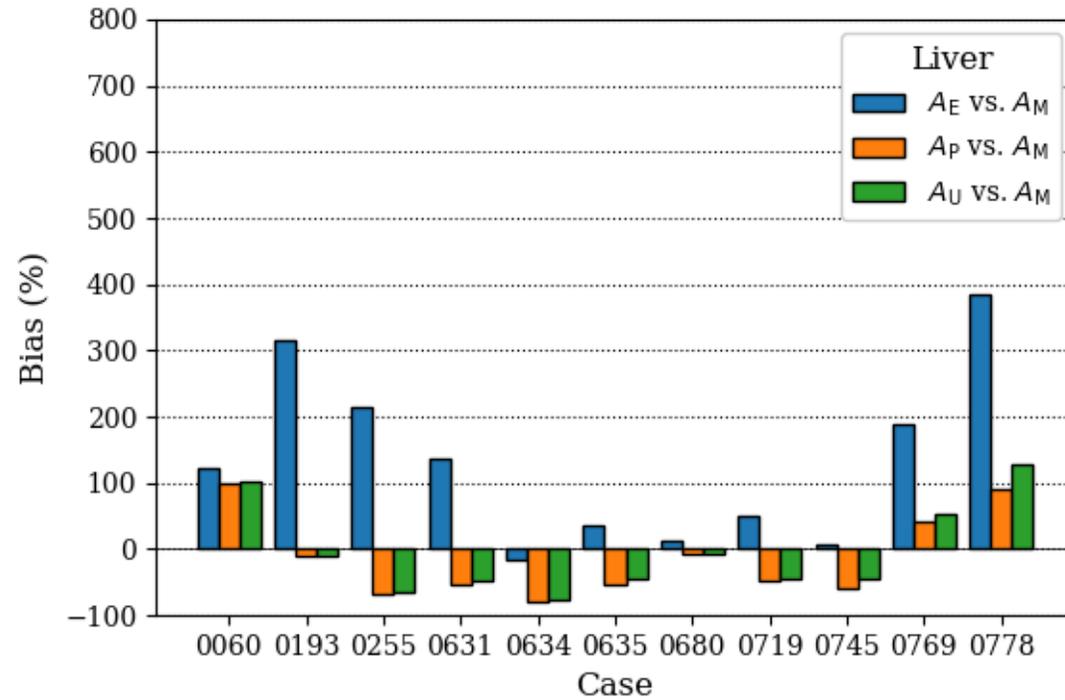
Mean absolute bias	Liver (%)	Skeleton (%)
A_E vs. A_M	135±132	208±217
A_P vs. A_M	56±64	33±46
A_U vs. A_M	57±70	32±46

Skeleton-to-Liver Activity Ratio
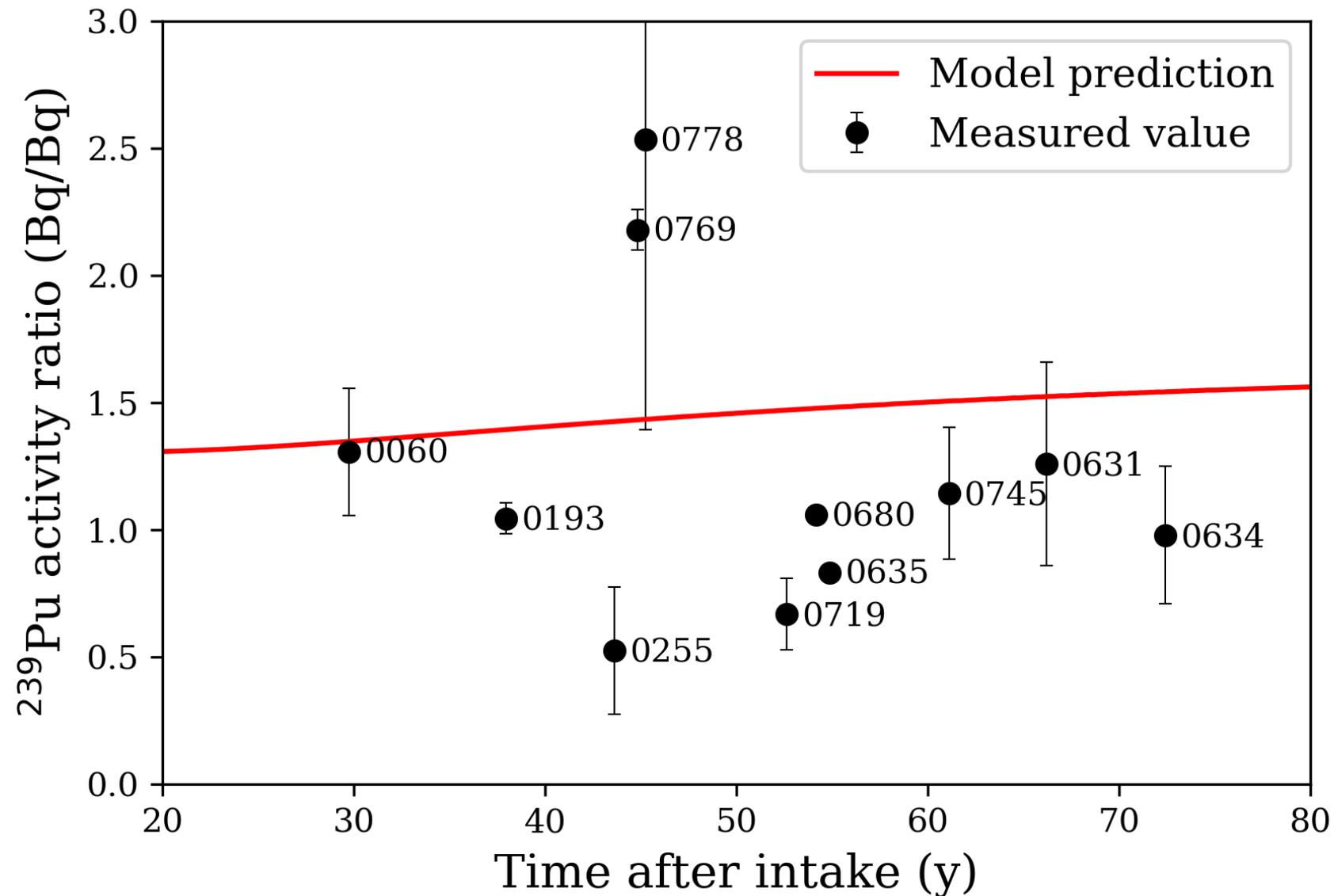
Bias in Liver+Skeleton Activity
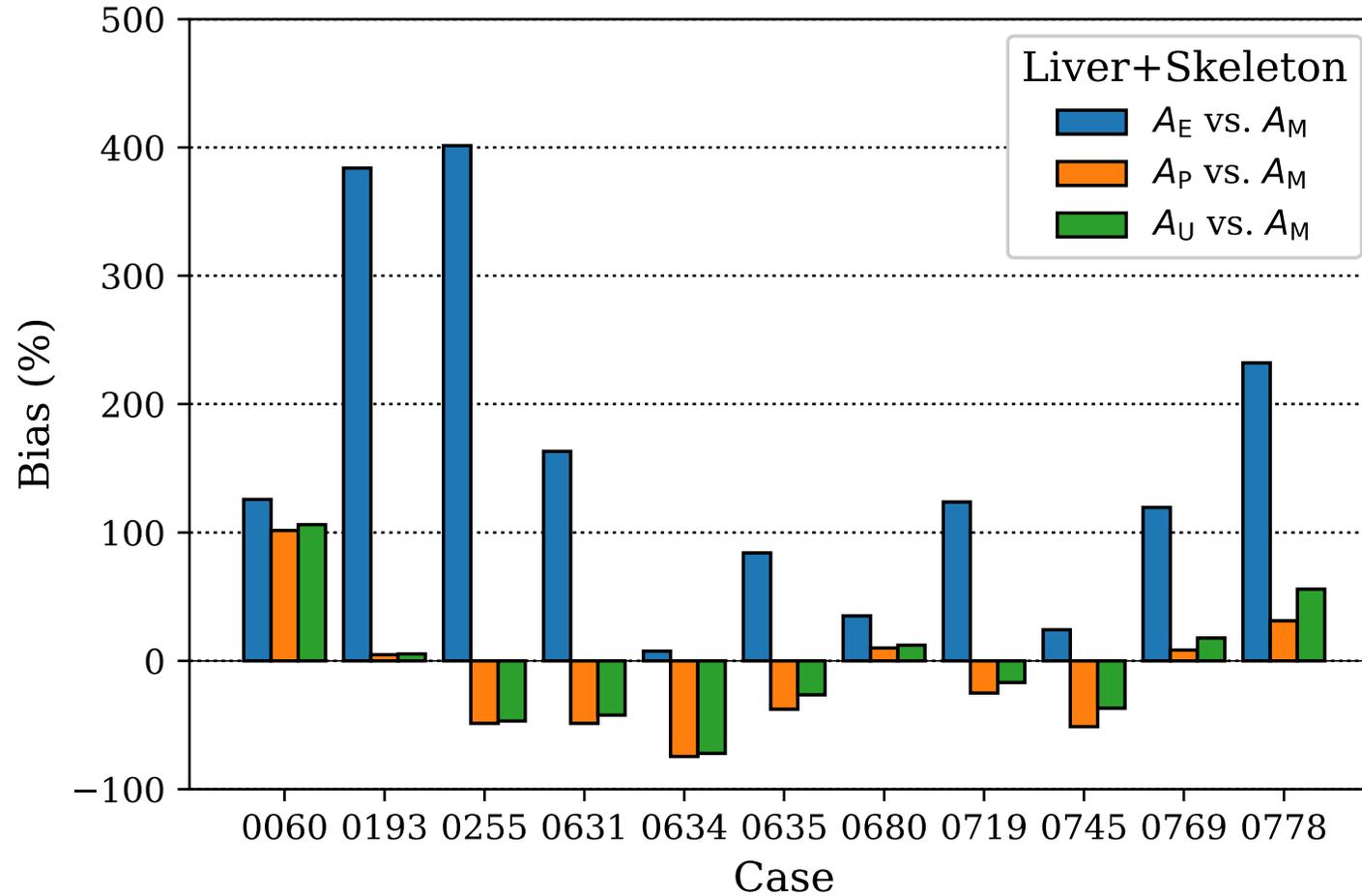
Mean absolute bias (%)	
A_E vs. A_M	155±134
A_P vs. A_M	40±50
A_U vs. A_M	40±51

Conclusions

For this study group:

- Using only urine data collected during exposure period overestimated the plutonium liver+skeleton (systemic) activity by factor of 2.6
  - Number and quality of the early urine measurements
  - Uncertainty of the intake scenario (time)

- Using all urine data including post-exposure follow-up measurements improved the activity estimate
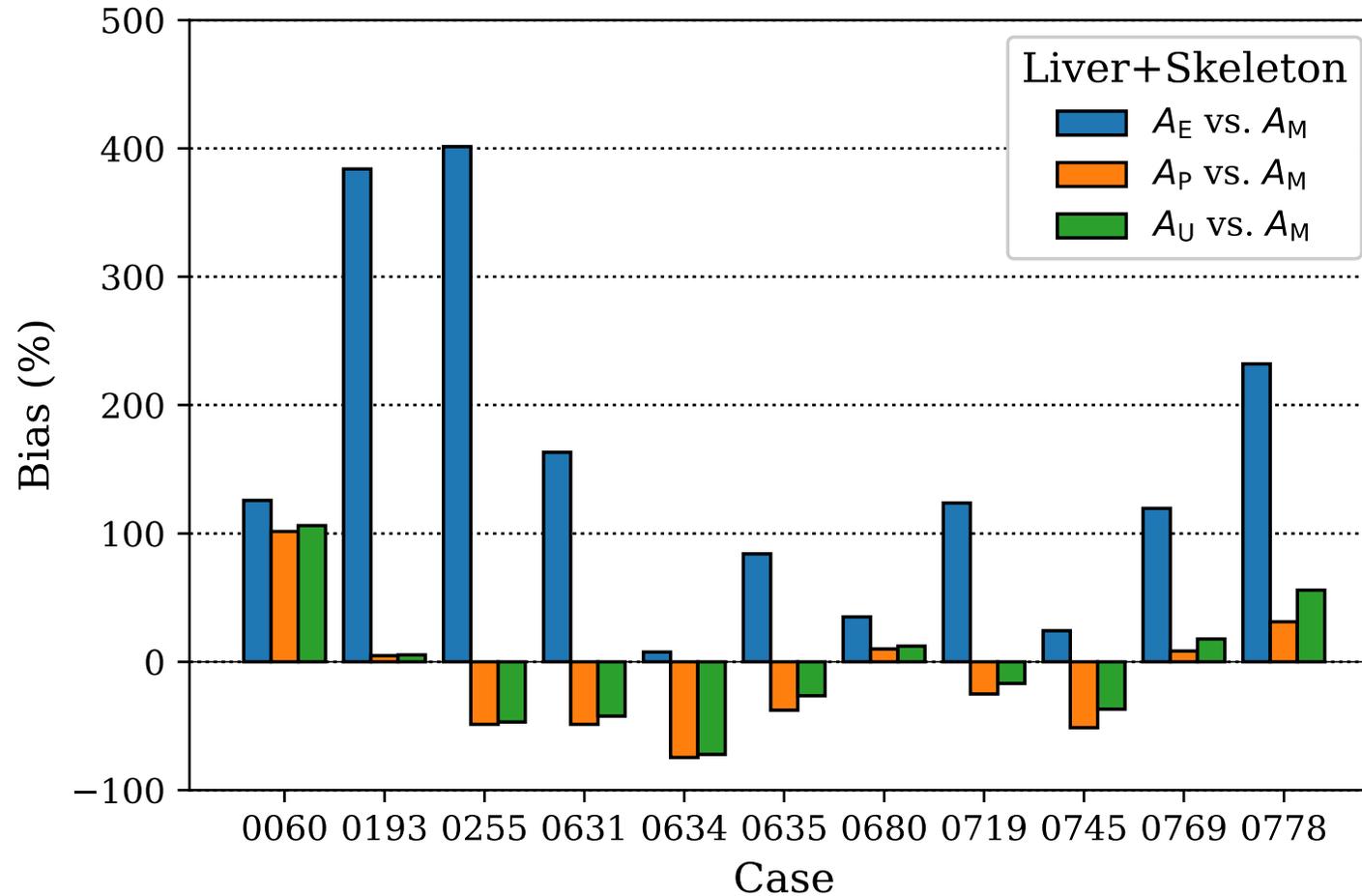 - The estimate was driven by post-exposure follow-up data

Thank you!

Bias in Liver+Skeleton Activity

Mean bias (%)	
A_E vs. A_M	155±134
A_P vs. A_M	−12±50
A_U vs. A_M	−4±51

Mean absolute bias (%)	
A_E vs. A_M	155±134
A_P vs. A_M	40±50
A_U vs. A_M	40±51