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Uncertainty Analysis on Organ Activities and Doses from Plutonium Intake

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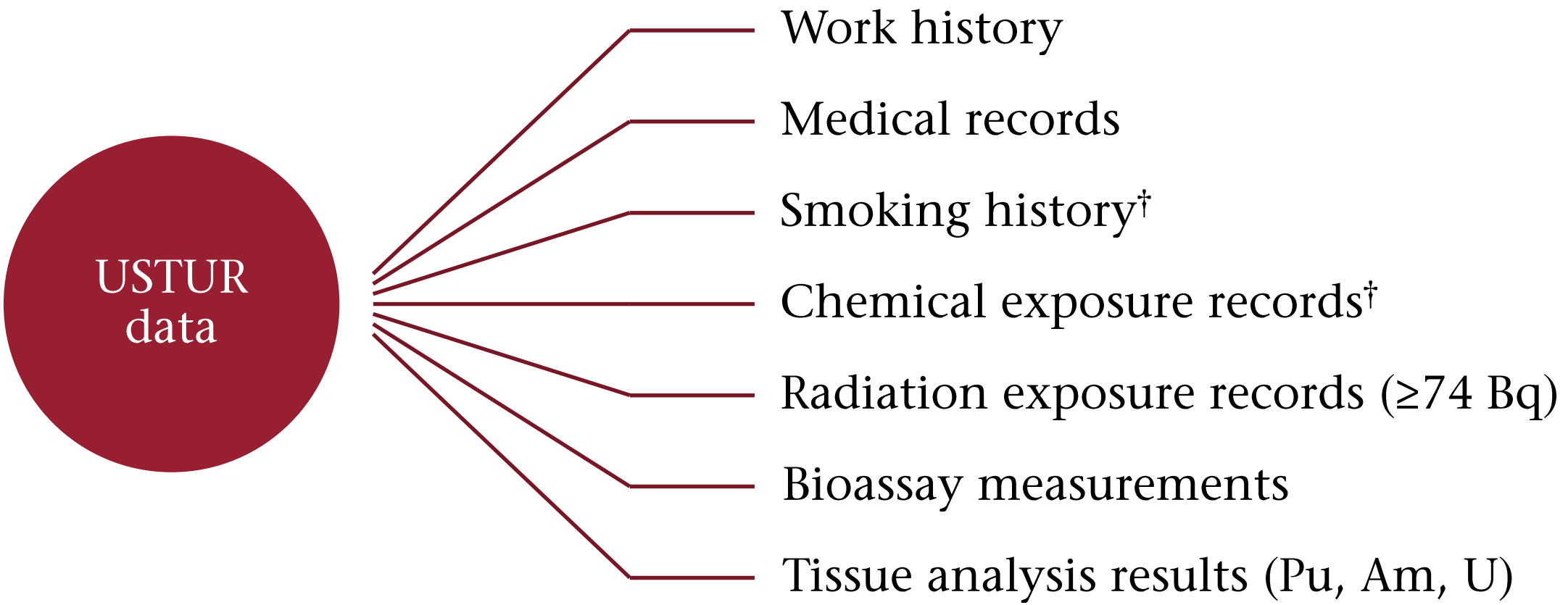
Motivation

- In radiation epidemiology worksite documentation and bioassay measurements are used to estimate the dose
- Post-mortem tissue/organ analyses can be used to evaluate the accuracy of the standard dosimetry for radiation epidemiology

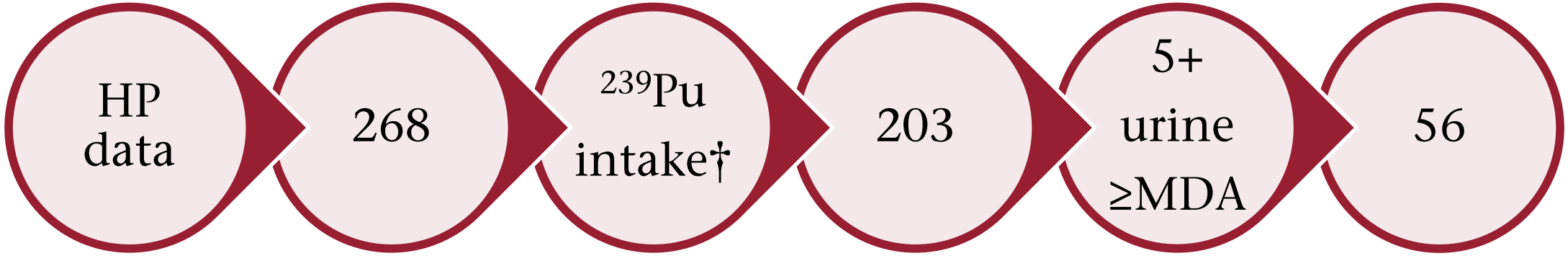
Unique data resource



† - self-reported data

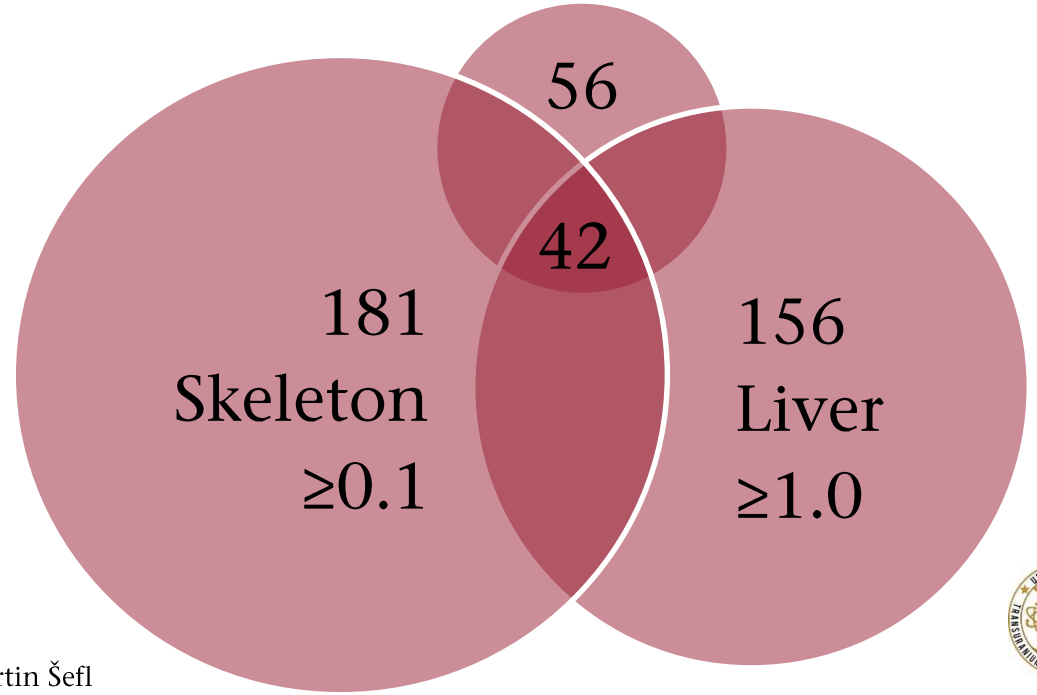
Initial case selection criteria

- Urine data points



† - no extensive chelation

- Tissue concentration, Bq kg^{-1}

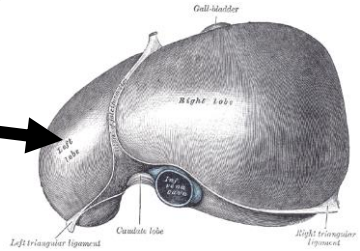


Studied cases

- Studied cases: 9 whole-body, 3 partial-body
- Route of intake: inhalation, wound
- Plutonium material: $Pu(NO_3)_4$, refractory PuO_2
- Worksite estimate of systemic deposition: 30 Bq – 3.7 kBq

Study objectives

- Comparison of plutonium activity in liver and skeleton predicted from urine bioassay with post-mortem radiochemical analyses
- Comparison of equivalent doses based on urine bioassay with doses based on post-mortem tissue radiochemical analyses

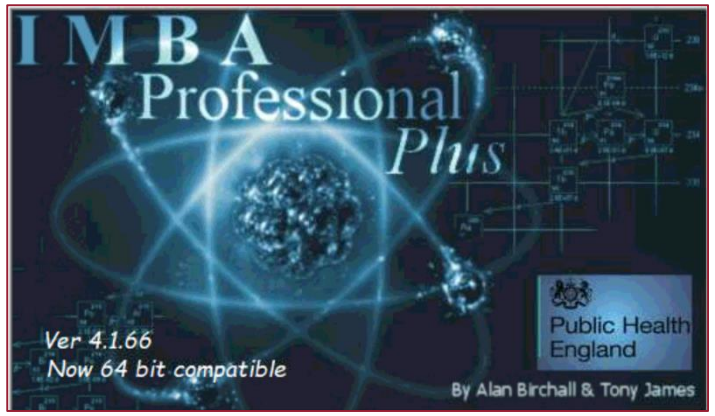


Bioassay Monitoring at Los Alamos: *A Guide for workers and their families.*

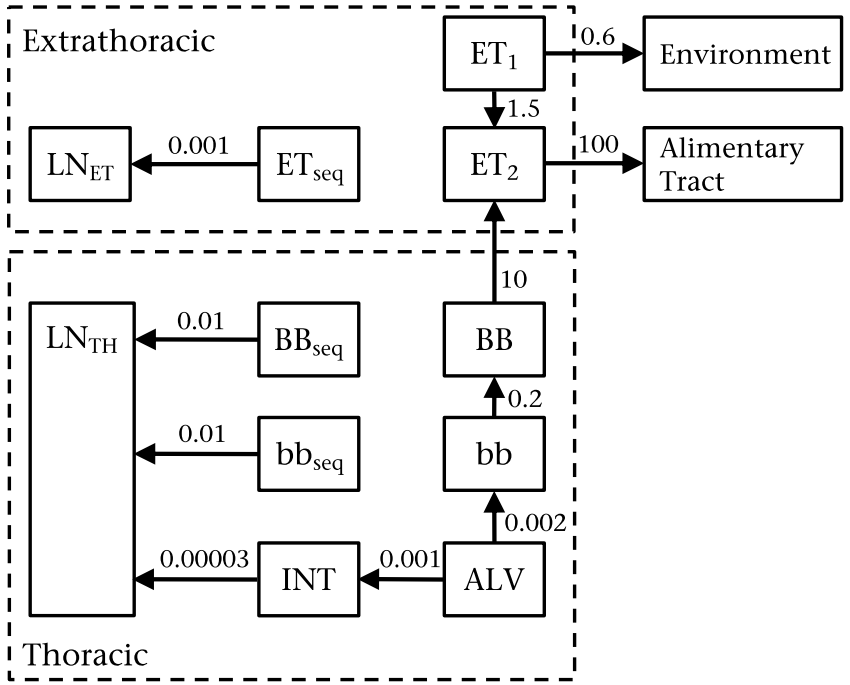
Henry Gray. *Anatomy of the Human Body*

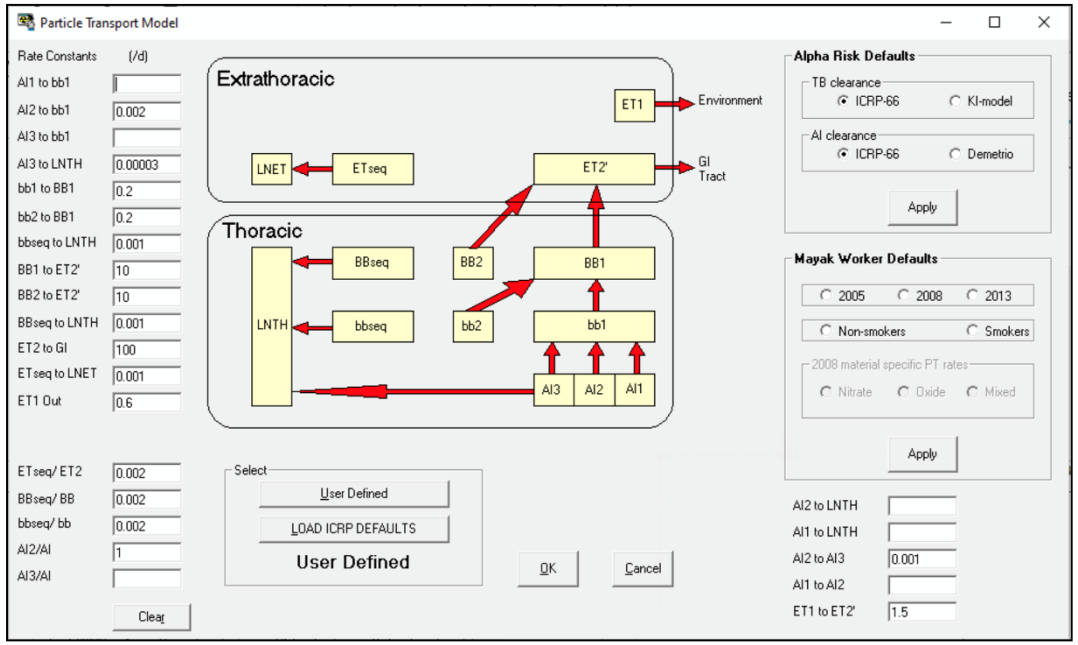
https://www.turbosquid.com/3d-models/human-female-skeleton-pose/1025026

Bioassay calculations



- IMBA Professional Plus
- ICRP 130 HRTM, ICRP141 Pu systemic model, NCRP 156 wound model
- Default model assumptions
- Maximum likelihood fit





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	70–80 bone samples (half of the skeleton)	Measured
Partial body	2–8 bone samples	Estimated*

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

Bias: activity

- IMBA fit of urine bioassay to estimate intake
- Predict plutonium activities A_u (Bq) in liver and skeleton at the time of death
- Compare to measured post-mortem organ activities A_{pm}

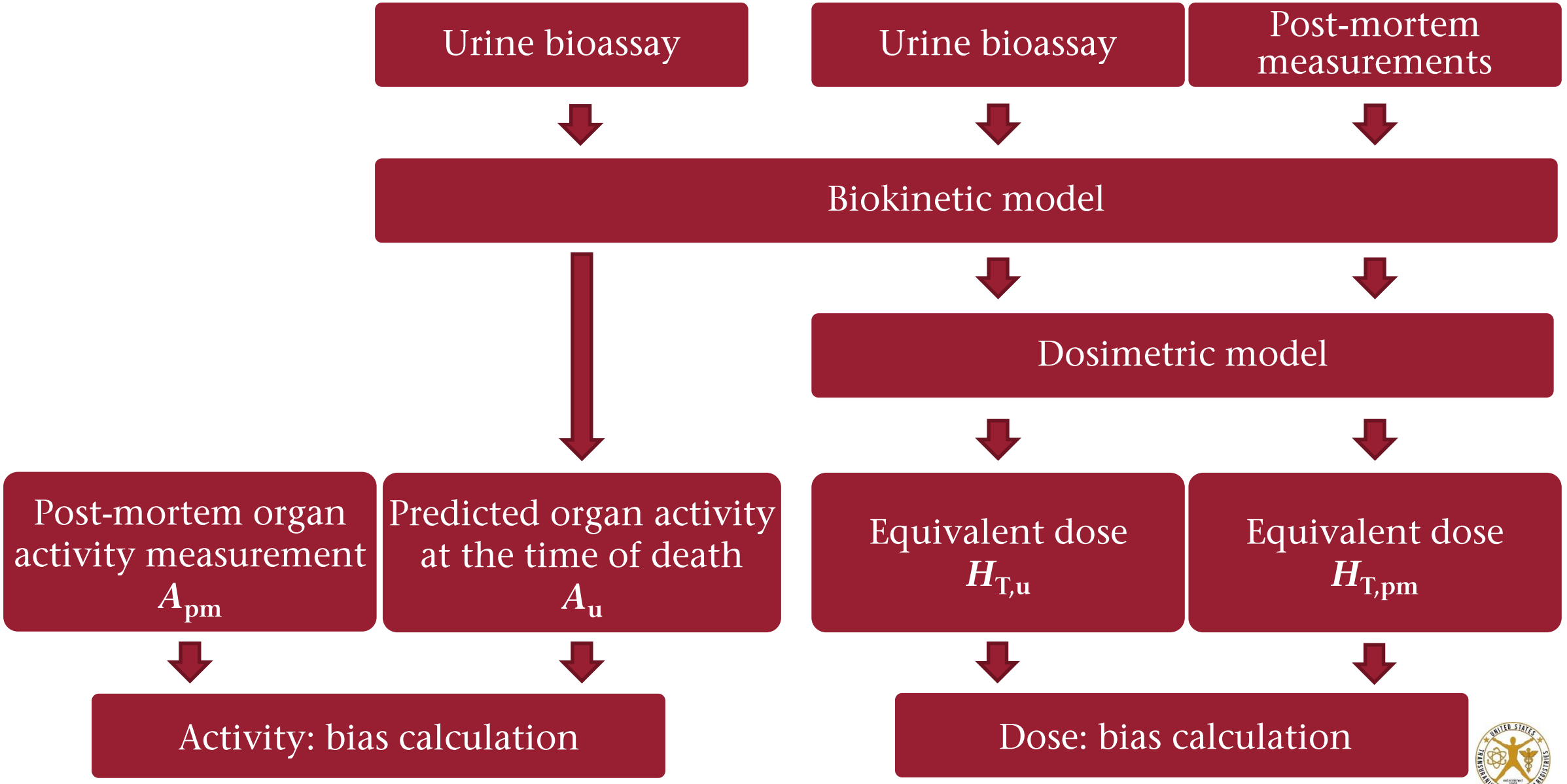
$$\text{Bias}(\%) = \frac{A_u - A_{pm}}{A_{pm}} \times 100$$

Bias: equivalent dose

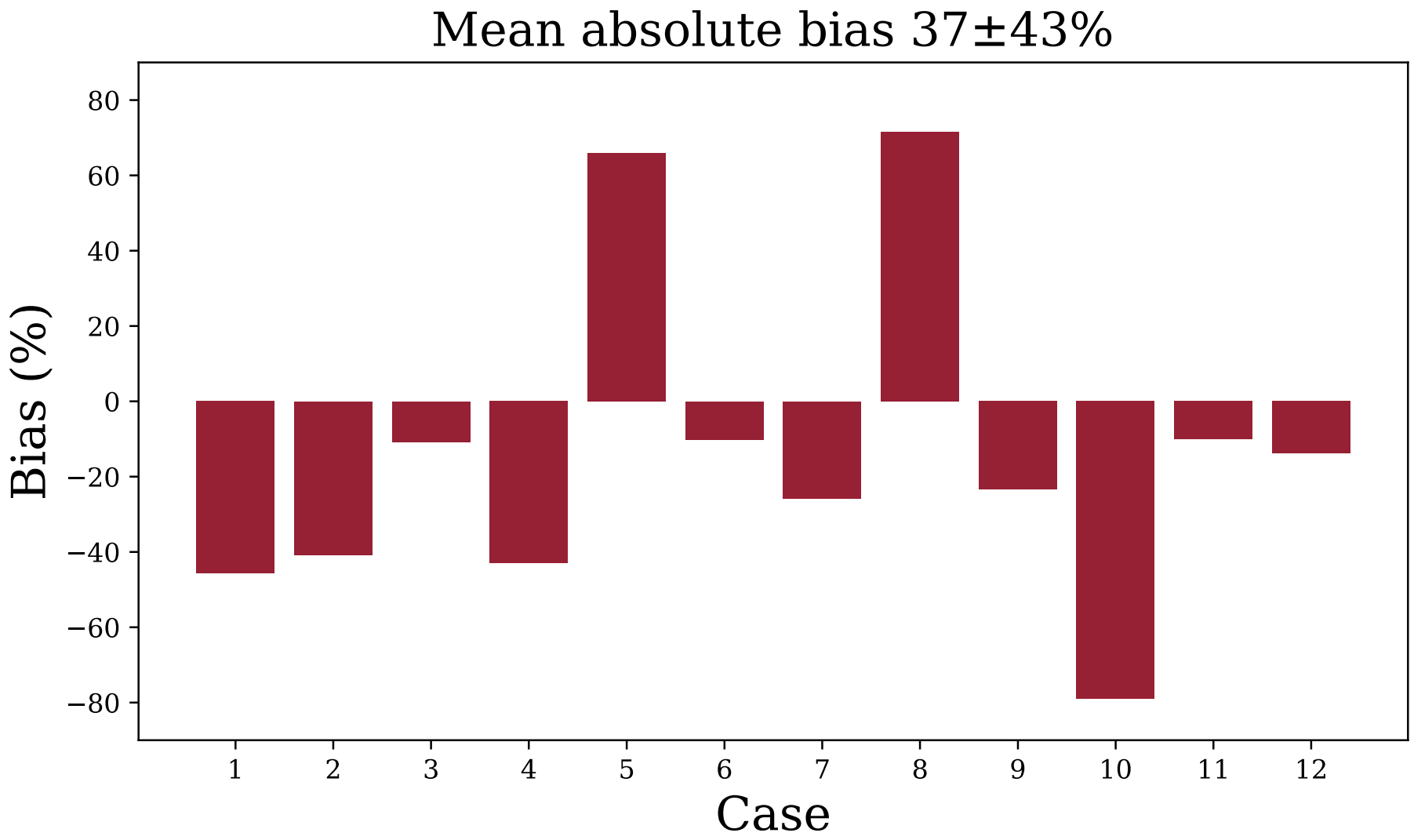
- IMBA fit of urine bioassay to estimate intake: calculation of equivalent doses (Sv) in the liver and skeleton – $H_{T,u}$
- IMBA fit of the post-mortem activities to estimate intake: calculation of equivalent doses in the liver and skeleton – $H_{T,pm}$

$$\text{Bias}(\%) = \frac{H_{T,u} - H_{T,pm}}{H_{T,pm}} \times 100$$

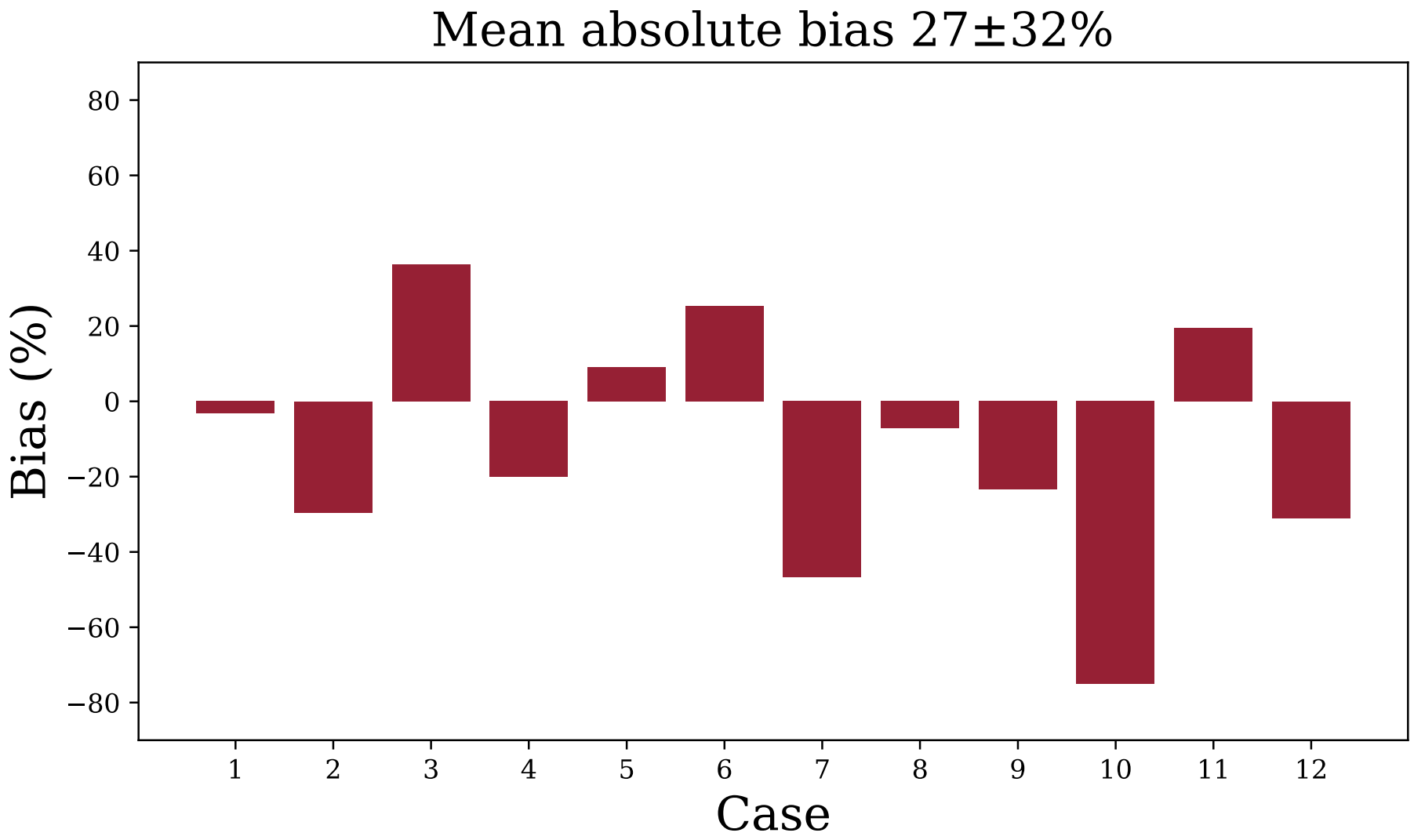
Bias in activity vs. Bias in dose



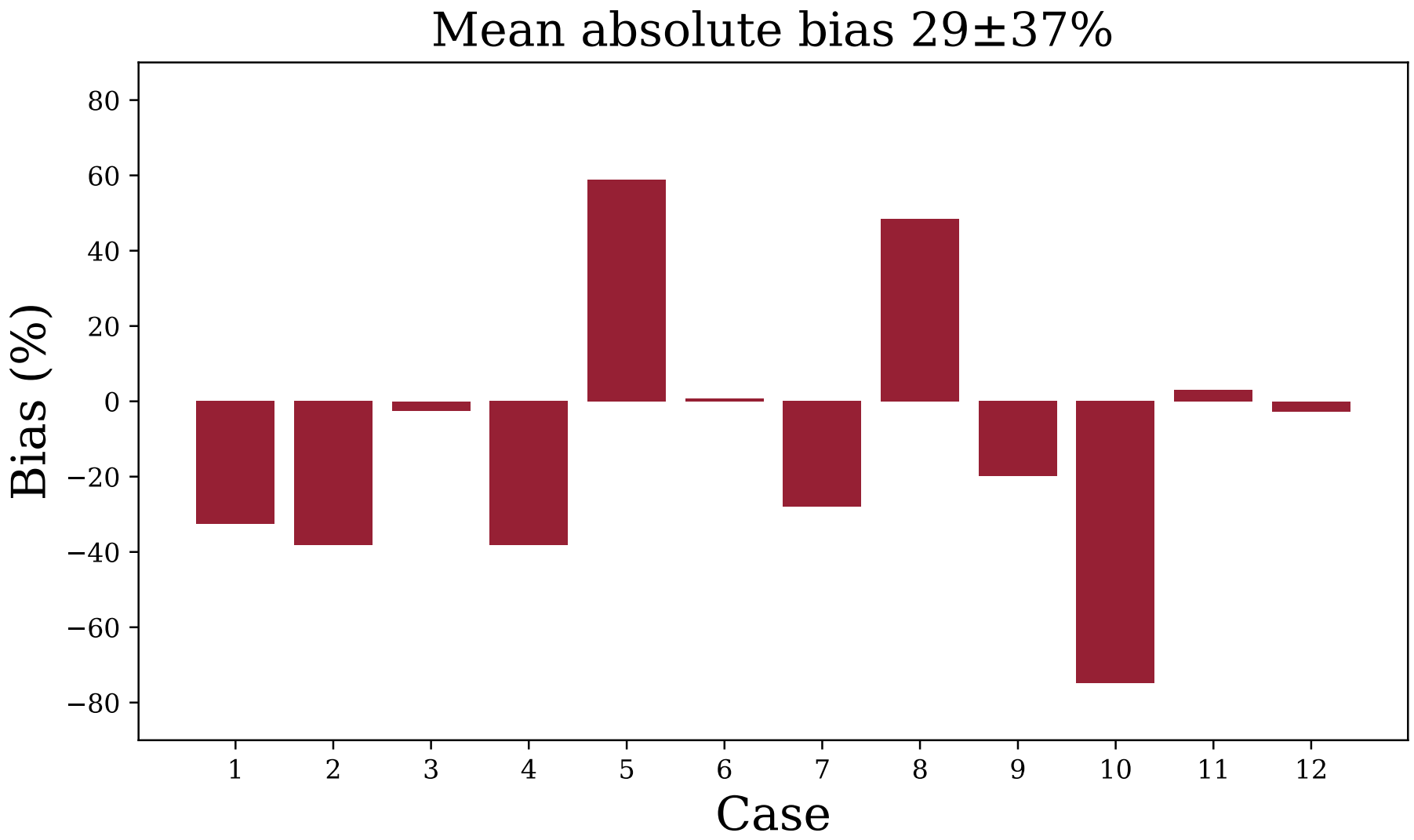
Bias: liver activity at the time of death



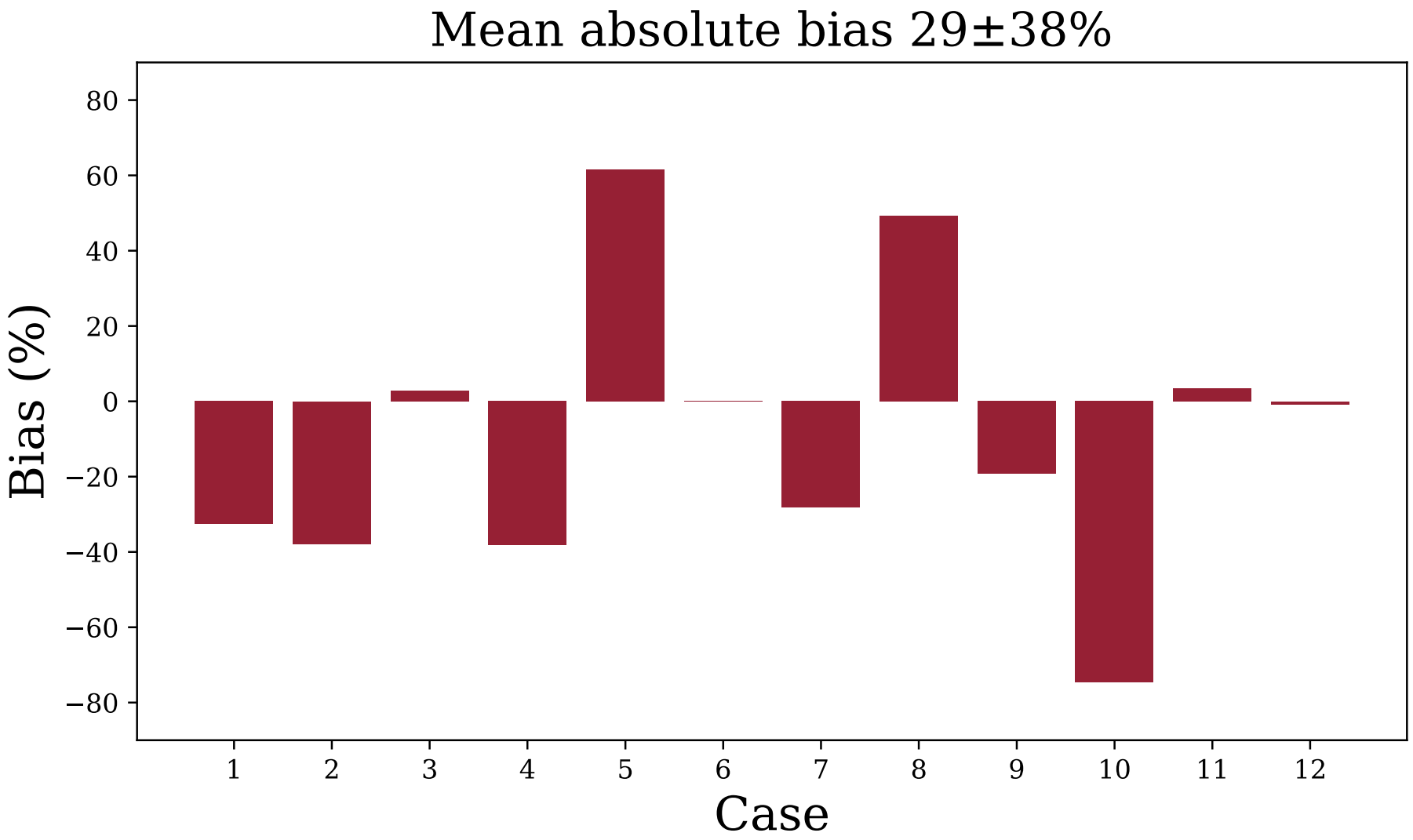
Bias: skeleton activity at the time of death



Bias: equivalent dose to the liver



Bias: equivalent dose to the skeleton



Summary

Organ activity (Bq)

Mean absolute bias ± SD:

- Liver: 37 ± 43%
- Skeleton: 27 ± 32%

Equivalent organ dose (Sv)

Mean absolute bias ± SD:

- Liver: 29 ± 37%
- Skeleton: 29 ± 38%

Conclusions

- Twelve cases were evaluated using IMBA Professional Plus
- Predicted skeleton and liver activities at the time of death differed from the measured values on average by 27% and 37%, respectively
- Skeleton and liver doses calculated from urine measurements were both on average within 29% of those calculated from post-mortem results

Thank you!