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USTUR Studies: An Update

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"Learning from Plutonium and Uranium Workers"

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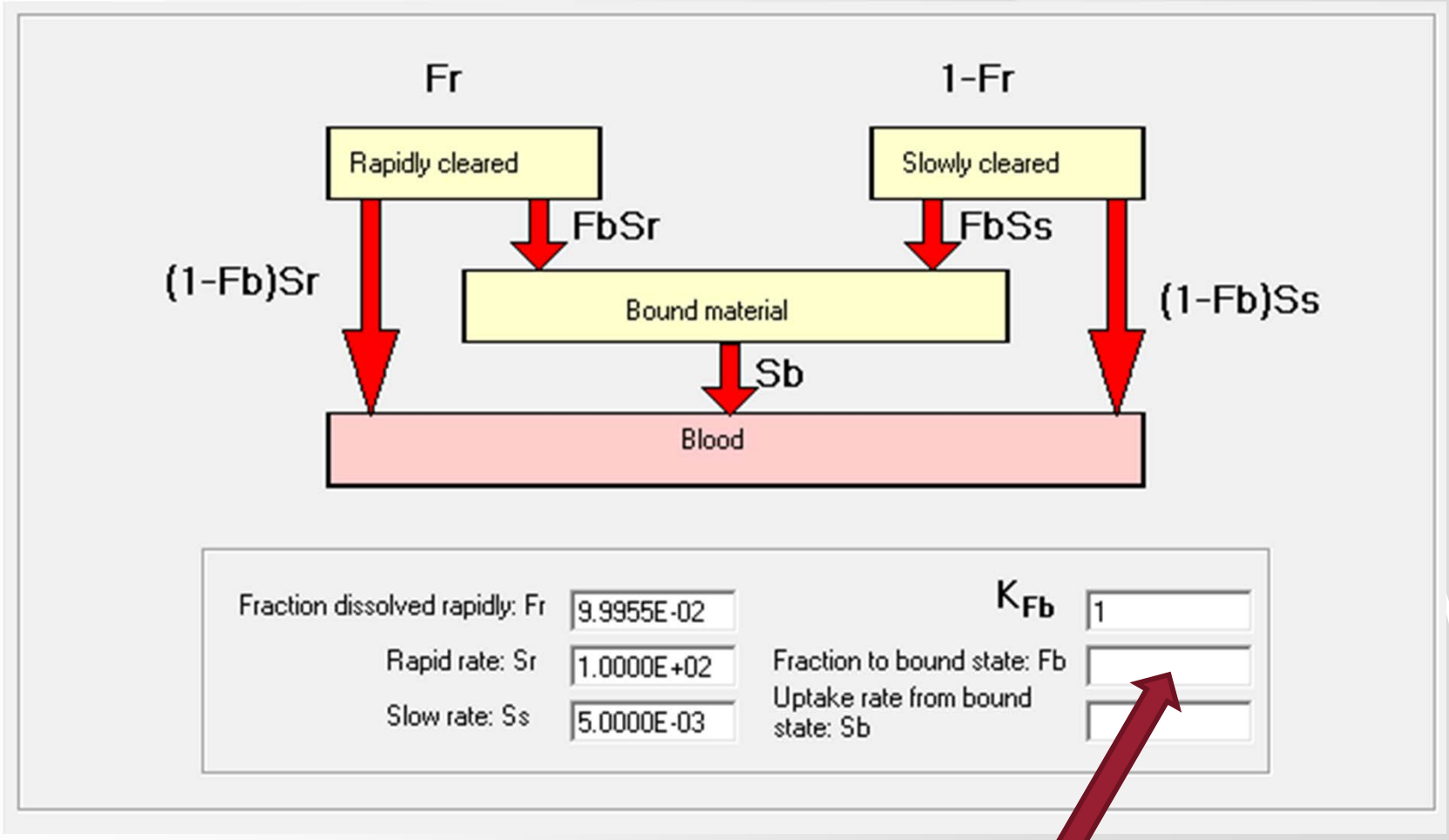
Outline

- Bound Fraction (HPA/PNNL/USTUR)
- 'Best' Bone (USTUR)

HPA/SOLO Project

- Grant from Health Protection Agency (UK) "*to quantify the fraction of the initial deposited activity which is still retained in the upper airways due to binding (f_b), taking account of particle transport from the deep lung; and characterize the deposited activity in terms of its particulate or diffuse nature in bronchial epithelium, lung parenchyma and lymph nodes.*"
- Period: October 1, 2012 – July 30, 2013.
- Budget: €16,000 ($20,992) – Funded.

Testing HRTM Absorption Model



ICRP default assumption: $f_b = 0$

USTUR Whole Body Case 0269

- Acute inhalation of $^{239}Pu(NO_3)_4$ aerosol mist
- Chelated
- 31 y of follow-up measurements
- Died 38 y after intake
- $^{239,240}Pu$ activity in body organs, Bq
  - ✓ Lungs & LNTH 26.9
  - ✓ Liver 937.0
  - ✓ Skeleton 1197.0

Case 0269: Analysis of Intake

- IMBA Expert™ USDOE-Edition
- Exclude data affected by chelation
- Maximum likelihood fit to:
  - ✓ Urinary and fecal excretion data
  - ✓ Total Pu Lung/LNTH activity measured at DOD
- Results:
  - ✓ Intake ≈ 58 kBq
  - ✓ AMAD ≈ 2 μm
  - ✓ GI absorption fraction, $f_1 \approx 0.0005$
  - ✓ $f_r \approx 0.09$, $s_r \approx 110\ d^{-1}$, $s_s \approx 0.02\ d^{-1}$
  - ✓ Bound fraction, $f_b \approx 8\%$
  - ✓ $s_b \approx 0.0002\ d^{-1}$

James et al (2007) RPD.

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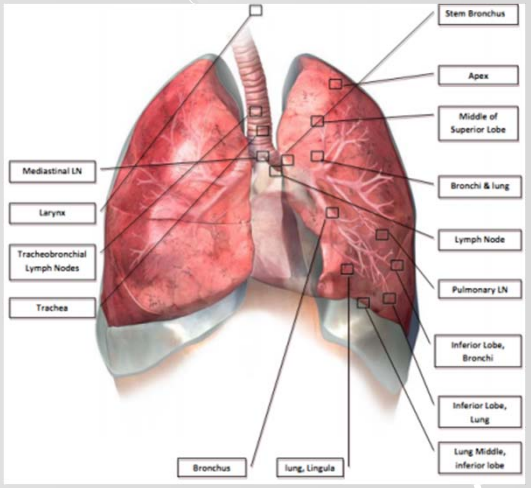
M.S. Project (WSU/PNNL)

Christopher E. Nielsen

Microdistribution and Long-Term Retention of $^{239}Pu(NO_3)_4$ in the Respiratory Tract of USTUR Registrant 0269

- Techniques:
  - ✓ Autoradiography
  - ✓ Immunohistochemistry
  - ✓ Real-time PCR analysis
- Summary:
  - ✓ Non-uniform distribution in lung
  - ✓ No observable ^{239}Pu associated with bronchi
  - ✓ Sub-pleural scarring and fibrosis of alveolar septa (~79%)
  - ✓ Plutonium and cigarette residues sequestered in fibrotic scar tissues



Nielsen et al (2012) Cancer Res.

USTUR Whole Body Case 0631

- Acute inhalation of $^{239}Pu(NO_3)_4$ in 1940s
- Worksite estimates
  - ✓ Intake: ~2.3 kBq
  - ✓ Body burden in 1969: ~1.46 kBq
- Not chelated
- Non-smoker
- Died from complications of Alzheimer disease 66 years post-intake

Ph.D. Project (WSU/PNNL)

Christopher E Nielsen

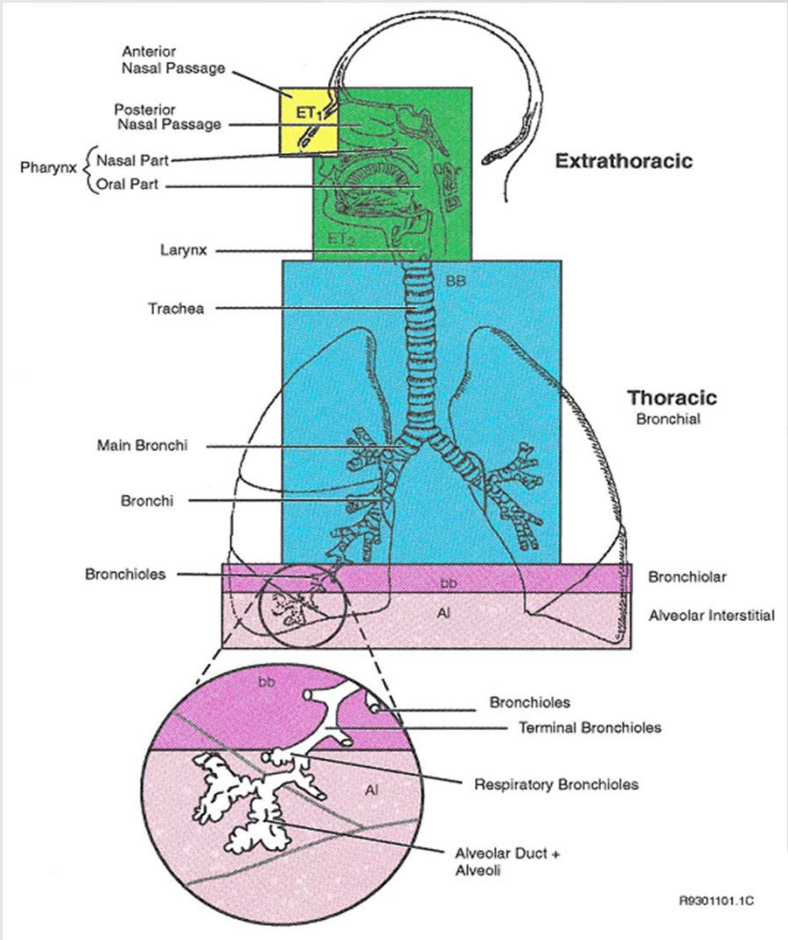
Scoping the Problem

- Radiochemistry results on bone: 5.5 Bq kg^{-1}
- Estimated total skeletal content: 53.7 Bq
- Estimating intake using default ICRP assumptions
  - ✓ Absorption Type M
  - ✓ No bound fraction
- IMBA estimate of intake: ~3.0 kBq
- Activity of Pu in lungs at DOD
  - ✓ f_b=2%: 21 mBq
  - ✓ f_b=8%: 85 mBq

Detectable!

Distribution and Quantification

- Autoradiography
- Immunohistochemistry
- Radiochemical analysis
  - ✓ BB
  - ✓ bb
  - ✓ AI
- Biokinetic modeling
- Uncertainty analysis



'Best Bone' Project

Slide 1

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European Radiation Dosimetry Group
(EURADOS) WG7 Plenary Meeting
Gent, Belgium, 14-16 September, 2011

From Single Bone Analysis to Total Skeleton Content

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Goal – Task – Benefits

- Goal: *Precise estimation of skeleton content based on a limited number of bone analyses (partial-body donor, biopsy.)*
- Task: *Define the 'best bone' (or group of bones) for the estimation of total actinide content in the skeleton.*
- Benefits: *Reduction of uncertainties when estimation actinide content from partial-body analyses. Optimization (reduction) of number of bone samples in whole-body analysis.*

Methodology and Criteria

- Ratio = $\dfrac{\text{Individual Bone Concentration}}{\text{Total Skeletal Concentration}}$

- 'Best bone' = $\dfrac{C_{bone},\ Bq\ kg^{-1}}{C_{skeleton},\ Bq\ kg^{-1}}$ $\rightarrow 1 \pm (TPU \rightarrow min)$

Individual Bone Selection

Case	Age, y	Osteo-porotic	Primary Nuclide	Cbone /Cskeleton					Variability by Case
				Ribs	Stern.	Vert.	Patella	Clavic.	
0193	62		^{239}Pu	0.77	1.24	1.10	1.21	1.04	1.07±0.19
0208	69		^{239}Pu	0.74	1.29	0.62	1.24	1.00	0.98±0.30
0212	56	no	^{239}Pu	0.74	1.03	0.75	2.06	1.18	1.15±0.54
0213	68	no	^{239}Pu	0.86	1.18	1.06	1.42	0.87	1.08±0.23
0242	77		^{239}Pu	0.68	0.95	0.78	1.28	1.05	0.95±0.23
0259	55	no	^{238}Pu	0.64	0.65	0.63	1.66	0.81	0.88±0.44
0425	83	no	^{239}Pu	1.61	1.10	1.46	0.51	0.99	1.13±0.43
0679	72	yes	^{239}Pu	1.29	0.62	1.13	-----	1.04	1.02±0.29
0720	84	yes	^{239}Pu	0.70	0.71	1.16	0.91	1.22	0.94±0.24
0744	67	no	^{239}Pu	1.2	-----	0.98	1.27	1.00	1.11±0.14
0269	79	yes	^{239}Pu	0.91	1.01	1.01	1.16	1.05	1.03±0.09
0682	71	no	^{238}Pu	1.09	0.80	1.23	1.41	0.67	1.04±0.30
12	70 ±10	all	Pu	0.94 ±0.30	0.96 ±0.24	0.99 ±0.25	1.28 ±0.39	0.99 ±0.15	Variability by Bone

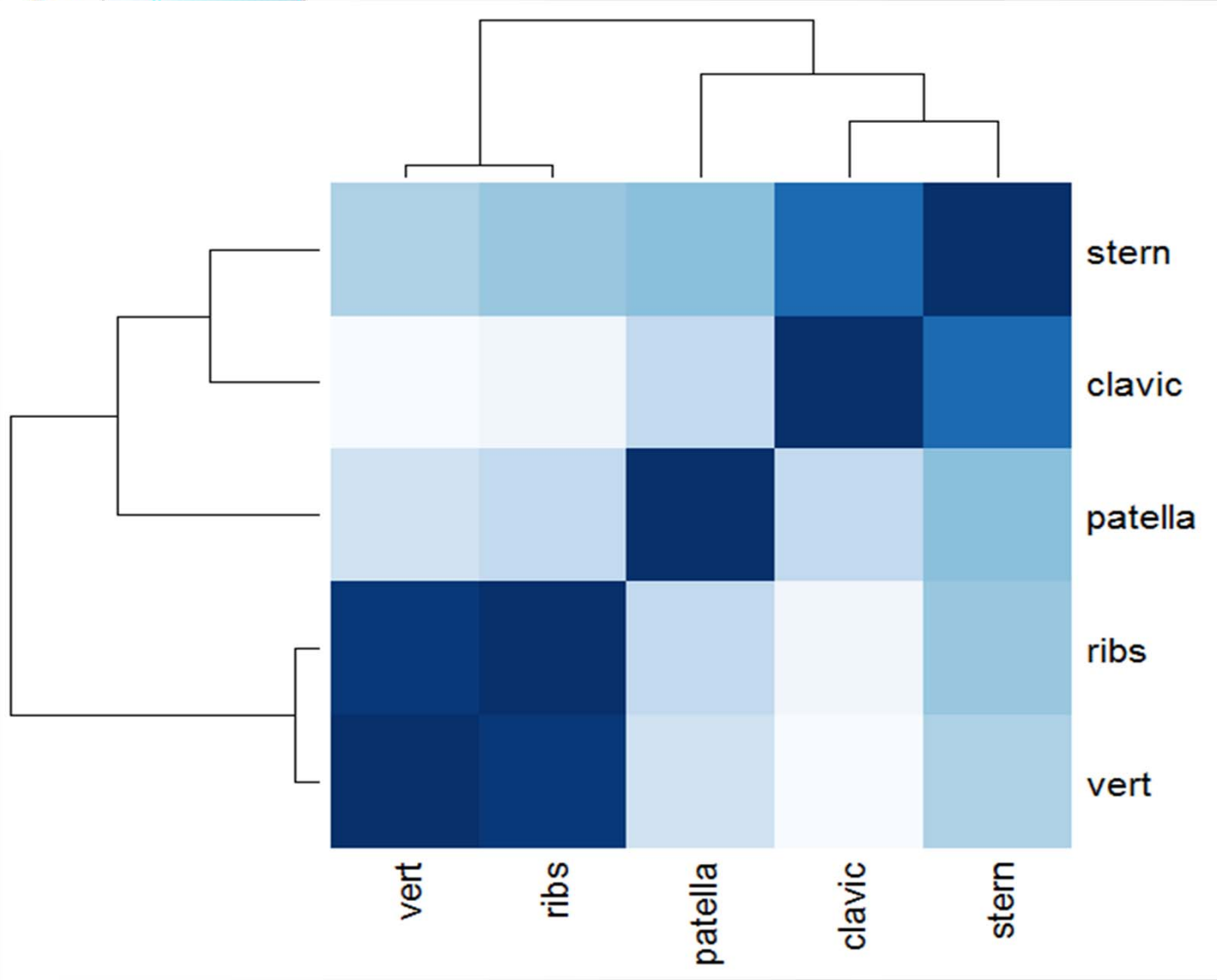
Bone Group Selection

- Objective: *the best linear combination that gives least relative uncertainty*

$$\text{'Best Group'} = \frac{\Sigma A_i \times C_{bone,i}}{C_{skeleton}} \rightarrow 1 \pm (\text{UNC} \rightarrow \text{min})$$

- Approach: *glmulti - automated model selection by minimizing Akaike Information Criterion* ***AIC = 2k – 2ln(L)****, where* ***k*** *is the number of parameters of the model,* ***L*** *is the maximized likelihood*
- Software: *R*

Correlation of Relative Measurements Between the Bones



'Best' Group

- Bones: vertebra, patella clavicle
- Coefficients:
  - ✓ vertebra – 0.340
  - ✓ patella – 0.226
  - ✓ clavicle – 0.373
- Activity Ratio:
  - ✓ $R_{group} = 0.99 \pm 0.08$
  - ✓ $R_{clavicle} = 0.99 \pm 0.15$

Work in Progress

- Revision of radiochemistry data (skeleton) for 16 whole body cases.
- Calculation of weighted-average actinide skeletal concentration, $C_{skeleton}$, Bq kg^{-1}.
- Calculation of $^{238,239}Pu$ activity ratio (R) C_{bone} /$C_{skeleton}$ for 6 bones: *rib, clavicle, patella, sternum, vertebrae, femur (MS)*.
- Calculation of 95% CI for R values.