EURADOS/REMPAN Wound Contamination Project

Annex 1: Example of Plutonium Contaminated Wound

Maia Avtandilashvili
United States Transuranium and Uranium Registries
College of Pharmacy and Pharmaceutical Sciences
Washington State University, Richland, WA, USA
INTRODUCTION

The United States Transuranium and Uranium Registries (USTUR) maintain an extensive and growing database of health physics information and measured actinide concentrations of tissues for former workers who were known to have had intoxications of actinides during their employment in the nuclear industry. These registries have volunteered to donate tissues after their death for radiocanonical analysis and biodiagnostic modelling studies. Case 0262, the subject of this study, is of particular interest since his intakes were well documented, and he occurred as two discrete (acute) inhalation events, with a further intake via a cutaneous puncture wound during the 1950s into the late-1960s. Case 0262 is a study of the immediate radiation exposure, for whom USTUR has characterised radiochemically the contents of $^{239,240}$Pu and $^{238}$Pu in all major soft tissue organs and individual bone.

*Corresponding author: gemes@tcityx.wsu.edu

RESULTS

An analysis of the biodiagnostic modelling of $^{238}$Pu and $^{239,240}$Pu in the tissue samples from Case 0262 was conducted. The biodiagnostic modellings of $^{238}$Pu and $^{239,240}$Pu were performed using two distinct datasets. For $^{238}$Pu, the biodiagnostic modellings were performed using both the Chatterjee et al. (2006) and Zeng et al. (2010) datasets. For $^{239,240}$Pu, the biodiagnostic modellings were performed using the Chatterjee et al. (2006) and Zeng et al. (2010) datasets.

CONCLUSIONS

The biodiagnostic modellings of $^{238}$Pu and $^{239,240}$Pu in the tissue samples from Case 0262 were consistent with the intakes of $^{238}$Pu and $^{239,240}$Pu as documented by USTUR. The biodiagnostic modellings of $^{238}$Pu and $^{239,240}$Pu were also consistent with the intakes of $^{238}$Pu and $^{239,240}$Pu as documented by the Chatterjee et al. (2006) and Zeng et al. (2010) datasets.

Shane N. Weber,* Richard R. Brey,* and Anthony C. James†

INTRODUCTION

A breach of the skin poses a risk of internal deposition and translocation of radiotoxic material within the human body. Also, deposition of radioactive material at the wound site may be of concern because of the radiobiological effects on cells involved in proliferation rapidly due to the physical injury. Tumor development at the wound site has been observed in several animal studies (Guillemin and Darby 2003). There have been over 2.0 reported cases of skin injury involving radioactive contamination. Radionuclide-contaminated wound exposures were given a great deal of attention immediately after the Gulf War, where many soldiers were injured by depleted uranium shrapnel. More than 90% of radionuclide-contaminated wounds in the nuclear industry have involved injury to the hands (primarily the fingers) or arms. Most (90%) of these wounds involved mechanical damage to the skin. The rest involved chemical or thermal burns (NCRP 2006). The NCRP Report 156 focused on the intake of actinides through skin punctures on the hands or arms because of the high proportion of intakes involving these scenarios. An inadequate amount of human data unaffected by medical intervention (wound care, excision and/or ablation) is available to exhaustively validate the models of retention and translocation of radioactive material in contaminated wounds. Experimental animal data has been extrapolated to humans in the development of the currently recommended model for radionuclide-contaminated wound exposures (NCRP 2006). Intakes through wounds differ significantly from inhalation intakes because of the heightened pathophysiologic response of nearby tissue. Inhala- tion and ingestion intakes are better understood than wound intakes because they are better understood from the standpoint of radiobiological processes. Wound intakes are usually harder to quantify than are inhalation and ingestion intakes because of the nature of the interaction of homestasis often associated with wound intakes.

Shane N. Weber,* Richard R. Brey,* and Anthony C. James†

SHAWN N. WEBER, RICHARD R. BREY, AND ANTHONY C. JAMES

Advance Access publication 30 January 2007

USTUR Whole-body Case 0262: 33-YEAR FOLLOW-UP OF PU, IN A SKIN WOUND AND ASSOCIATED AXILLARY NODE


U.S. Transuranium and Uranium Registries, College of Pharmacy, Washington State University, 1445 Terminal Drive, Suite 201, Richland, WA 99354, USA

Department of Mechanical, Industrial and Nuclear Engineering, University of Cincinnati, 590 Rhodes Hall, Cincinnati, OH 45221, USA

Pacific Northwest National Laboratory, PO Box 999, Richland, WA 99354, USA

2543 Harris Avenue, Richland, WA 99354, USA
Case Description

- Worked as an engineer at Nuclear Defense Facility for 31 years
- Routinely monitored for internal exposure to plutonium via bioassay measurement program: urinalyses, in vivo chest counts
- Several skin and workplace contamination incidents reported
- Two suspected plutonium inhalation intakes
- Major plutonium contaminated wound intake 1.5-y later
- Worksite estimate of $^{239}$Pu systemic deposition: 2.3 nCi (84 Bq)
- Died from hepatocellular carcinoma 33 y after wound intake

Weber SN et al. (2012). Health Phys. 103(3): 286-300
Contaminated Wound

- Injured finger on a broken drill while working in a glovebox
- Hood glove was contaminated to >40000 dpm (667 Bq)
- Laceration on left thumb: 0.6-cm long and 0.13-cm deep
- No apparent bleeding noted
- External measurement of the wound site: 500 dpm (8.3 Bq)
  - Decontaminated using pHisohex
- No chelation therapy and/or surgical excision attempted
Available Bioassay Data

- Five in vivo chest counts during last three years of employment: *all negative*
- Total of 86 Urine measurements over 30 years: *mostly positive after wound*
Autopsy Tissue Analyses

- Two samples of skin and muscle from left thumb containing the wound analyzed separately by $\gamma$-spectrometry and ICP-MS
- 83 soft tissue samples and 145 bones analyzed using $\alpha$-spectrometry
- Analysis results published by James et al. (2007) and Weber et al. (2012)
Distribution $^{239}\text{Pu}$ in organs/tissues

Whole-body activity: $221.8 \pm 7.2$ Bq

Unpublished data revised from James et al. (2007) and Weber et al. (2012)
USTUR Case Evaluations
James et al. 2007

- Multiple intake regimes: two inhalations and wound
- Ad hoc wound model, ICRP 66 HRTM & ICRP 67 Pu systemic model
- Birchall and James (1989) ‘rate matrix’ to solve compartmental models
  ✓ Selected model parameters optimized
- Simultaneous fit to all urine and tissue retention data
  ✓ Measured wound activity: 68 Bq – 51% lower than actual retention
- Estimated intakes:
  ✓ Inhalations – insoluble Pu: (1) 757 Bq and (2) 1504 Bq
  ✓ Wound – 86% insoluble & 14% soluble Pu: 204 Bq
- Total committed effective dose: 35 mSv
Weber et al. 2012

• Single wound intake assumed
• NCRP 156 wound model & ICRP 67 Pu systemic model
• IMBA Professional Plus®: Maximum likelihood fit to urinary excretion
  ✓ Deposition category ‘Fragment’ best described data
  ✓ Model underestimated long-term wound and whole-body retention
• IMBA Uncertainty Analyzer: Weighted Likelihood Monte Carlo Sampling
  ✓ Posterior mean wound retention function:
  \[ R(t) = 0.0342e^{-1.38t} + 0.117e^{-0.0112t} + 0.849e^{-0.00000269t} \]
  ✓ Estimated posterior mean values (95% CI):
    Intake: 222 ± 6 Bq (210 Bq – 234 Bq)
    CED: 19.0 mSv (18.8 mSv – 52.3 mSv)
Current Work (I)

TAURUS internal dosimetry software, Version A_0.1
- Strongly retained soluble Pu assumed
- Urine bioassay only
- Intake: 34.4 Bq
- CED: 8.45 mSv
Current Work (II)

- Simultaneous fit to urine & post-mortem wound retention
- Mixture: 16.3% ‘Soluble Strong’ + 83.7% ‘Fragment’
- Intake: 196.1 Bq
- CED: 9.2 mSv
Current Work (III)

- Simultaneous fit to urine & post-mortem wound, liver, skeleton
- Mixture: 17.2% ‘Soluble Strong’ + 82.8% ‘Fragment’
- Intake: 199.2 Bq
- CED: 9.8 mSv
Summary

EURADOS/REMPAN Wound Contamination Project, Annex 1
- USTUR whole body Case 0262
- Plutonium contaminated laceration
- No surgical excision or chelation
- 33 years of follow-up: urine bioassay, tissue retention data
- Two case evaluation studies published
- Final data analysis in progress
Questions?

m.avtandilashvili@wsu.edu