Application Of Voxel Phantoms For Internal Dosimetry At IRSN Using A Dedicated Computational Tool (OEDIPE)


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Voxel-based phantoms

Phantom characteristics
- Realistic and accurate models
- Voxel geometry + Monte Carlo code

Drawbacks
- Use of phantoms already created from anatomical database
- Variation of anatomical parameters

Specific voxel-based phantoms

Visible man
VIP-Man
(Xu et al., RPI, United States)
Is it possible to develop procedures to create specific numerical phantoms?

How to easily handle the association of specific numerical phantoms with Monte Carlo codes?

The OEDIPE tool (GUI)

- Fast creation of specific voxel phantoms (CT, MRI images)
- Automatic creation of the MC input file (MCNP/MCNPX)
- Automatic process and display of the requested results
Application fields of OEDIPE
(French acronym for Tool for Personalized Internal Dose Assessment)

Internal dosimetry

- Radiation Protection (Contamination)
- Nuclear Medicine (Internal Radiotherapy)
- In vivo counting
- Internal dose assessment
General principle of OEDIPE

Images (CT, MRI)

Source description

- Photon spectrum in detector(s) for \textit{in vivo} calibration
- Dose assessment

Images segmentation
- Specific threshold tool based on the Hounsfield scale (hard bones, lungs, soft tissues and air)
- Link to external software: ImageJ, Dosigray® (semi-automatic method by outlining)

Each voxel linked to a density value and a material composition (ICRU 44)

- Nature
- Activity
- Position (point, organ, fraction of organ)
General principle of OEDIPE

1. Input data processing
   - Images (CT, MRI)
   - Source description
   - Photon spectrum in detector(s) for in vivo calibration
   - Dose assessment

2. MCNP/MCNPX input file
   - Number of cells < 100000
     - Voxel coupling (Borisov, 2002)
     - Repeated structure
General principle of OEDIPE

1. Images (CT, MRI)
2. Source description
3. Monte Carlo Calculation
4. MCNP(X) Output file
5. Results processing

- Photon spectrum in detector(s) for *in vivo* calibration
- ORGAN DOSE
- SPATIAL DOSE DISTRIBUTION
- Comparison simulation/measurement
- MCNP/MCNPX input file
Computer time for dose assessment

Study for photons
1 million of histories

1 DAY
$10^6$ VOXELS

~1h30
$3.5 \times 10^6$ VOXELS

Using a Power Mac G5 2Ghz bi-processor, MCNPX2.5d/e, lattice tally speed up ($\sigma < 10\%$)

Mean organ doses in a few (minutes – hours)
Voxel level dose distribution in a few days
**OEDIPE validation works**

**In vivo counting**

- Biological samples (Borissov et al., Health Phys. 83, 2002)
- Lung counting (Pierrat et al. Transac. Nucl. Sc. submitted)
- Whole Body Counting (de Carlan et al., RPD in press)

**Dose assessment**

- EGS4/MCNPX with the Zubal phantom (Chiavassa et al., RPD in press)
- MCNP4B/MCNPX considering published data (Chiavassa et al., RPD in press)
- Comparison OEDIPE simulations/TLD measurements
**In vivo applications of OEDIPE**

- **Comparison of lung calibration phantoms**
  (Franck et al., RPD 105 2003)

- **High energy measurement**:
  - Is IGOR representative to a real subject?
  - Influence of source distribution on calibration factors
    (de Carlan et al. IM 2005 conference)

- **Animals experimentations**
  (with IBPH, Moscow, Borissov and al., MC2005)
Dose assessment applications of OEDIPE

- Dose assessment of a case of defective technetium 99m labeling of a bone scanning agent  
  (Chiavassa et al., in press)

- Personalized expertise of a wound contamination  
  (de Carlan et al., 2003)

- Impact of morphology on S factors
Expertise of a $^{106}$Ru wound contamination

Context

- Point $^{106}$Ru contamination by puncture

- Measurement of the worker by the medical service:
  - negative urine $\rightarrow$ no systemic burden
  - $\rightarrow$ fixed dust
Expertise of a $^{106}$Ru wound contamination

$A_{\text{max}} = 69 \text{ Bq the 06/06/00}$

At 4 mm in depth
Expertise of a $^{106}\text{Ru}$ wound contamination

$H_{\text{skin}}(50) = 445 \text{ mSv}$
Impact of the morphology on S factors

Sophie Chiavassa, PhD student

\[ \frac{S_{\text{max}}}{S_{\text{min}}} \text{ for the 9 patients} \]

<table>
<thead>
<tr>
<th>Source organs (Uniform }^{131}\text{I distribution)</th>
<th>Target organs</th>
<th>Lungs</th>
<th>Spleen</th>
<th>Kidneys</th>
<th>Liver</th>
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<td>Liver</td>
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<td>2.0</td>
<td>2.2</td>
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<table>
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<tr>
<th>Weight (kg)</th>
<th>Height (m)</th>
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<td>59</td>
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<td>90</td>
<td>1.80</td>
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</table>
Impact of the morphology on S factors

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Variations of S factors between patients and the male adult considered in MIRDOSE 3

\[ S_{\text{Patient}} - S_{\text{Male adult}} \]

\[ S_{\text{Male Adult}} \]

→ Self irradiation
- without mass correction < 124%
- with Olinda mass correction < 5.5%

→ Cross irradiation < 103%
Conclusions

OEDIPE is a convenient tool to handle specific voxel phantoms: fast creation, automatic association with MCNP(X) and processing of the desired results.

OEDIPE's potential was demonstrated in in vivo counting and internal dose assessment.
Prospects

**In vivo calibration and internal contamination**

- Implementation of biokinetic models within OEDIPE
- Inter comparison of voxel phantoms in whole body counting within the European CONRAD project

**Internal radiotherapy**

- OEDIPE is currently taking part in clinical essay involving patients in the treatment of Hepatocellular Carcinoma using Lipiodol
Within the Phantom consortium

- Voxel phantoms that could be shared

IGORs

LIVERMORE

JAERI

MIRD
Within the Phantom consortium

OEDIPE should be available under specific agreement conditions