Dosimetry for medical cohorts: The eye lens


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Introduction

- The effect of ionising radiation to the lens of the eye
  - Numerous epidemiological studies, different populations
  ⇒ Lower dose threshold than previously considered

  - ICRP 103 (2007):
    - threshold dose of 2 Gy (acute exposure) and 5 Gy (protracted exposure)
    - occupational dose limit: 150 mSv/year
  - ICRP 118 (2012):
    - threshold dose of 0.5 Gy
    - occupational dose limit: 20 mSv/year

- Relationship ‘radiation dose – effect’ not clear in low dose region
  ⇒ Requires sound effort for the assessment of eye lens dose
  ⇒ European EURALOC project; target population: interventional cardiologists
    - Relatively large population
    - Higher eye lens doses than other healthcare professionals
    - Last years a lot of focus on eye lens dose assessment
    - Increased risk on radiation-induced lens opacities already observed
Introduction

- **Latin America [Vaño, 2010]**
  - Posterior subcapsular opacities: 38% (58 IC) ↔ 12% (93 controls)

- **Asia [Ciraj-Bjelac, 2010]**
  - Posterior subcapsular opacities: 52% (56 IC) ↔ 9% (22 controls)

- **Finland [Mrena, 2011]**
  - 57 exposed physicians: 8 nuclear; 3 cortical; 2 PSC opacities

- **France [Jacob, 2013]**
  - Posterior subcapsular opacities: 17% (106 IC) ↔ 5% (99 controls)

- **Latin America [Vaño, 2013]**
  - Posterior subcapsular opacities: 54% (50 IC)

⇒ **Dosimetry**
  - relied on number of working years, predefined scatter doses
  - 1 study used whole body doses as surrogate for eye lens doses
EURALOC project

Objective:
- 440 interventional cardiologists
- 285 unexposed people

Multi-national study, a common standardised protocol

Two complementary dosimetric approaches

A. Based on individual information on working history
   - Large database of eye lens doses per procedure is available
   - Corrected for changes in x-ray systems and procedures over the years (procedure before ’2000’)

B. Based on routine individual whole body dosimetry
   - Conversion factors from whole body dose → eye lens dose & associated uncertainty
Approach 1: Information on working history

- Questionnaire on occupational history
  - Divided in different working periods (≠ places)
  - Individual protective equipment and individual dosimetry
**Approach 1: Information on working history**

- Questionnaire on occupational history
  - Divided in different working periods (≠ places)
  - Individual protective equipment and individual dosimetry
  - Type of interventional cardiology procedures
    - Workload, x-ray system, collective protective equipment

  Given per decade
Approach 1

- Literature review
  - 82 papers read
    - 52% papers considered in first round
      - Eye lens dose data for interventional cardiology
      - Reduction factors of shielding (ceiling screen, lead glasses)
    - 3 additional studies with unpublished data

- Final selection
  - Raw data from the European ORAMED project
    - 580 measurement data from clinical practice in 6 different countries
  - 12 papers
    - Providing non-normalised eye lens dose data, measured in clinical practice
    - From 7 papers, the raw data received from the authors

- Data is divided according to
  - Type of procedure
  - The use of ceiling screen
  - The X-ray system configuration
    - Separately for left and right eye
Approach 1

- Resulting dose distributions: CA procedure; with ceiling screen

Tube below; Left eye
- Median dose: 18 µSv
- 95% CI [8; 135]

Biplane; Left eye
- Median dose: 32 µSv
- 95% CI [8, 126]
Approach 1

- Resulting dose distributions: RF ablations; Monoplane system

No ceiling screen; Left eye
- Median dose: 17 µSv
- 95% CI [4; 169]

Ceiling screen; Left eye
- Median dose: 18 µSv
- 95% CI [8; 57]
Approach 1

- Effect of lead glasses → Monte Carlo simulations
  - Including the effect of shape of the glasses
  - Including the effect of the rotation of the operator’s head

- Considering different relevant x-ray beam projections
- Considering different relevant operator positions

\[ \Rightarrow \text{Frequency distribution of } \frac{H_p(3)_{\text{with}}}{H_p(3)_{\text{without}}} \] (→ 180 simulations)
Approach 1

- Effect of lead glasses → Monte Carlo simulations

**Median:** 0.50
95% CI: [0.10, 0.96]

**Median:** 0.57
95% CI: [0.13, 0.88]
Approach 1: Summary

\[ H_p(3)_{\text{cum}} = \sum_i \sum_j D_{j,y,z} \times D \left( \frac{H_p(3)_{\text{with glasses}}}{H_p(3)_{\text{without glasses}}} \right)_{j,z} \times C_i \times N_{i,j,y,z} \]

- Distribution of eye lens dose data
  - Per type of procedure (\(j\))
  - With or without ceiling screen (\(y\))
  - Per type of x-ray system (\(z\))

- 8 types of procedures
  - Haemodynamic:
    - CA
    - CA&PCI
    - CTO
    - valvuloplasty
  - Electrophysiology
    - RF ablations
    - PVI
    - PM/ICD implantation
    - CRT-D

\(i\): decades
\(j\): type of procedure
Approach 1: Summary

\[ H_p(3)_{\text{cum}} = \sum_i \sum_j D_{j,y,z} \times D \left( \frac{H_p(3)_{\text{with glasses}}}{H_p(3)_{\text{without glasses}}} \right)_{j,z} \times C_i \times N_{i,j,y,z} \]

- For each type of procedure \((j)\), the relevant x-ray beam projections and operator positions are selected.
- The type of x-ray system is considered \((z)\).
- Correction accounting for evolution of the x-ray systems and the procedures:
  - Effect of frame rate
  - Effect of reference dose at the detector
  \(\Rightarrow\) Applied on procedures performed before ‘2000
  \(\Rightarrow\) \(x2\) or \(x4\) depending on the type of procedure
- Number of procedures performed per decade:
  - In a specific decade \((i)\)
  - For a specific type of procedure \((j)\)
  - With specific type of protection \((y)\)
  - For a specific system \((z)\)

Collected in the occupational questionnaire
Approach 2: Conversion from whole body doses

- European ELDO project (funded by DoReMi network)
  “Correlation between eye lens dose and whole body dose”

- Measurement of eye lens doses and whole body doses in clinical conditions
  - Operator: Rando-Alderson phantom
  - Patient: PMMA plates
  - Passive and active dosemeters
  - Measurements **above the lead apron**
    - Eye level
    - Collar level
    - Chest level
    - Waist level
    - Left – middle – right side
European ELDO project (funded by DoReMi network)

“Correlation between eye lens dose and whole body dose”

Clinical conditions
- Different x-ray beam projections
- Different operator positions with respect to the x-ray field
- Different x-ray beam energies
- Mono-plane and bi-plane x-ray systems

Without protection equipment
(lead glasses and ceiling-mounted screen)
Approach 2

<table>
<thead>
<tr>
<th>Distance_Projection</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  0cm_AP</td>
</tr>
<tr>
<td>2  0cm_PA</td>
</tr>
<tr>
<td>3  0cm_RAO</td>
</tr>
<tr>
<td>4  0cm_RLAT</td>
</tr>
<tr>
<td>5  40cm_AP</td>
</tr>
<tr>
<td>6  40cm_PA</td>
</tr>
<tr>
<td>7  40cm_RAO</td>
</tr>
<tr>
<td>8  40cm_LAO</td>
</tr>
<tr>
<td>9  40cm_RLAT</td>
</tr>
<tr>
<td>10 40cm_LLAT</td>
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<tr>
<td>11 40cm_PA_LLAT</td>
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<td>12 40cm_RAO30_LAO30</td>
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<tr>
<td>13 40cm_RAO45_LAO45</td>
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<tr>
<td>14 70cm_AP</td>
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<tr>
<td>15 70cm_PA</td>
</tr>
<tr>
<td>16 70cm_RAO</td>
</tr>
<tr>
<td>17 70cm_LAO</td>
</tr>
<tr>
<td>18 70cm_RLAT</td>
</tr>
<tr>
<td>19 70cm_LLAT</td>
</tr>
<tr>
<td>20 62cm_PA_LLAT</td>
</tr>
</tbody>
</table>

\[ \frac{H_p(3)}{H_p(10)} \text{ values for 2 field sizes and 3 beam energies} \]

Selection per type of procedure and type of x-ray system
- RF ablations:
  - 40 cm distance
  - PA ; RAO ; LAO ; LLAT (weighted frequency)

For each position of the whole body dosemeter

\[ D \left[ \frac{H_p(3)}{H_p(10)} \right] \]
Effect of lead glasses → Monte Carlo simulations

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<tbody>
<tr>
<td>1</td>
</tr>
<tr>
<td>0cm AP</td>
</tr>
<tr>
<td>2</td>
</tr>
<tr>
<td>0cm PA</td>
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<tr>
<td>3...5</td>
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<tr>
<td>...</td>
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<tr>
<td>6</td>
</tr>
<tr>
<td>40cm_PA</td>
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<tr>
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<tr>
<td>40cm_RAO</td>
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<td>8</td>
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<tr>
<td>40cm_LA0</td>
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<td>40cm_RLAT</td>
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<td>10</td>
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<td>40cm_LLAT</td>
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<td>11...19</td>
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<tr>
<td>...</td>
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<tr>
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<td>62cm_PA_LLAT</td>
</tr>
</tbody>
</table>

\[ \frac{H_p(3)}{H_p(10)} \]

H_p(3)_{with}/H_p(3)_{without} for 2 shapes of glasses and 3 rotations

Selection per type of procedure and type of x-ray system
- RF ablations:
  - 40 cm distance
  - PA ; RAO ; LAO ; LLAT (weighted)

Effect of ceiling screen
- Affects both H_p(3) and H_p(10)
Approach 2: Summary

\[
H_p(3)_{cum} = \sum_i \sum_j H_p(10)_{i,j} \times D \left( \frac{H_p(3)}{H_p(10)} \right)_{j} \times D \left( \frac{H_p(3)_{with \ glasses}}{H_p(3)_{without \ glasses}} \right)_{j}
\]

\(i\): year
\(j\): type of procedure

Effect of lead glasses: Matching projection and distance

Yearly \(H_p(10)\) value (above the lead apron)

Conversion to \(H_p(3)\)
- No protection
- Ceiling screen

Graph: Conversion*shielding
- RF-ablation, chest-l-to-eyeLeft
- \(n=84\), median: 0.37, stdev: 0.82
Validation of methodology

- Eye lens dose measurements with cardiologists
  - Measurement of cumulative eye lens dose during 1 month → left and right eye
  - Collect occupational information for the measurement period
  - Collect corresponding Hp(10) value above lead apron

- $D_{\text{calc},A1} \leftrightarrow D_{\text{calc},A2} \leftrightarrow D_{\text{meas}}$
Validation of methodology

Measured value: 0.5 mSv

A calculated dose distribution (sampling 50,000 times) from approach 1 for one cardiologist

- Monoplane tube below system
- Ceiling shield and lead glasses
- 23 CA procedures
- 15 PCI procedures
Validation of methodology

- CA and PCI procedures
- Tube below mono plane system
- Ceiling shield and lead glasses

Eye lens dose [mSv]

Measurement
Approach 1
Approach 2
Conclusion

- The retrospective calculation of cumulative eye lens dose for interventional cardiologists

- 2 complementary approaches
  
  **Individual working history + eye lens dose data from literature**
  - **Direct** eye lens dose measurements
  - **Individual** occupational history
  - **Evolution** over the years
  - Consider the **number of procedures**

  **Conversion from whole body to eye lens dose**
  - **Use of personal** dose information of recruited cardiologist

- **Large spread** in available eye lens dose data
  - even for similar working practices
  - Confidence in **self reported** info from early years

- **Conversion** to eye lens dose
  - **Availability of $H_p(10)$** values above the apron
  - Very low confidence in **correct use of whole body dosimeter** in early years!
Thank you