Eye lens dosimetry: results from the ELDO project

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European ELDO Project

"European epidemiological study of radiation-induced cataracts for interventional cardiologists - Methodology implementation"

- Several European countries create a national cohort
- Joined analysis of the pooled European cohort
  ⇒ To elucidate further the reduction of the threshold for cataract (ICRP-118)
  ⇒ To confirm if there is a threshold

NEED FOR GOOD DOSIMETRY

USING THE SAME PROTOCOL
- Epidemiology part
- Dosimetry part

Acknowledgement: Funded by the DoReMi Network of Excellence
Eye lens dosimetry – 2 approaches

Approach #1: Correlation to Hp(10)

Estimating eye lens dose from whole body dose from routine monitoring → only dosimetric data available for past practices

Need for Hp(10) values above the lead apron

Approach #2: Recent data to past practices

Accounting for the evolution of X-ray systems

Need for precise information on workload, procedures, used equipment, etc.
Approach #1: Correlation to Hp(10)
Eye lens dosimetry – APPROACH 1

- 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

- ~ 50 experiments/set ups

Eye lens dosimetry – APPROACH 1

- 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 protective equipment (lead glasses and ceiling-mounted screen)

\[ \text{Result} = \frac{\text{eye lens dose}}{\text{whole body dose}} \text{ and associated uncertainty} \]

Based on spread between ratio's for different clinical configurations

Eye lens dosimetry – APPROACH 1

Ratio of average **left eye** lens dose and whole body dose measured at different locations, considering **all projections and operator positions**.

<table>
<thead>
<tr>
<th>Location</th>
<th>Collar L</th>
<th>Collar M</th>
<th>Collar R</th>
<th>Chest L</th>
<th>Chest M</th>
<th>Chest R</th>
<th>Waist L</th>
<th>Waist M</th>
<th>Waist R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>3.3</td>
<td>2.1</td>
<td>11.5</td>
<td>0.8</td>
<td>1.2</td>
<td>2.5</td>
<td>1.5</td>
<td>1.8</td>
<td>8.0</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>42%</td>
<td>48%</td>
<td>81%</td>
<td>90%</td>
<td>73%</td>
<td>100%</td>
<td>159%</td>
<td>143%</td>
<td>147%</td>
</tr>
</tbody>
</table>

Best correlation

Ratio of average **left eye** lens dose and whole body dose measured at different locations, considering projections and operator positions for **CA&PTCA and RF ablations**.

<table>
<thead>
<tr>
<th>Location</th>
<th>Collar L</th>
<th>Collar M</th>
<th>Collar R</th>
<th>Chest L</th>
<th>Chest M</th>
<th>Chest R</th>
<th>Waist L</th>
<th>Waist M</th>
<th>Waist R</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ratio</td>
<td>4.0</td>
<td>2.6</td>
<td>12.8</td>
<td>0.7</td>
<td>1.0</td>
<td>1.9</td>
<td>0.5</td>
<td>0.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>41%</td>
<td>40%</td>
<td>56%</td>
<td>52%</td>
<td>56%</td>
<td>50%</td>
<td>46%</td>
<td>64%</td>
<td>101%</td>
</tr>
</tbody>
</table>

Reduced uncertainties

Eye lens dosimetry – APPROACH 1

- Monte Carlo simulations: efficiency of the protective equipment

- Size, thickness and shape of **lead glasses**

Eye lens dosimetry – APPROACH 1

- Monte Carlo simulations: efficiency of the protective equipment

- Shape and position of ceiling suspended screens

Eye lens dosimetry – APPROACH 1

- Monte Carlo simulations: efficiency of the protective equipment

- For all possible x-ray projections, operator positions and tube configurations
- > 100 calculations

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left eye</td>
<td>0.18</td>
<td>0.57</td>
<td>0.44</td>
</tr>
<tr>
<td>Right eye</td>
<td>0.85</td>
<td>0.68</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Monte Carlo simulations: efficiency of the protective equipment

- For all possible x-ray projections, operator positions and tube configurations
- > 100 calculations

Result = correction coefficients considering effect of protection and associated uncertainty

Based on spread between coefficients for the variation in protection efficiency

<table>
<thead>
<tr>
<th>With / without</th>
<th>Left eye</th>
<th>Right eye</th>
<th>Collar</th>
<th>Chest</th>
<th>Waist</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead glasses</td>
<td>0.37</td>
<td>0.75</td>
<td>/</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>67%</td>
<td>34%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ceiling shields</td>
<td>0.45</td>
<td>0.42</td>
<td>0.53</td>
<td>0.63</td>
<td>0.80</td>
</tr>
<tr>
<td></td>
<td>86%</td>
<td>85%</td>
<td>71%</td>
<td>52%</td>
<td>24%</td>
</tr>
</tbody>
</table>

Eye lens dosimetry – APPROACH 1

Summary

- The correlation between eye lens and whole body dose depends on
  - Type of procedure
  - The position of the whole body dosemeter (always ABOVE lead apron)
  - The working practice
    - position of operator
    - The use of protective equipment

- Assessing eye lens dose from whole body dose can introduce large uncertainties
  - 40% to 160% without protection
  - Additional 35% to 85% for variation in protection efficiency

- Of interest for future retrospective epidemiological studies
- Not advisable for routine monitoring
Approach #2: Recent data to past practices
Eye lens dosimetry – APPROACH 2

- ORAMED database of eye lens dose measurements
  - 1329 eye lens dose measurements
  - 6 European countries; > 40 hospitals
  - Common dosimetry protocol
  - Several interventional procedures

  ⇒ Representative for current practices

- Adjusting recent data to past practices
  - Evolution of x-ray systems and interventional procedures
  - Interviews with manufacturers and interventional radiologists/cardiologists
Eye lens dosimetry – APPROACH 2

- Evolution of x-ray systems before year 2000:
  - **Beam filtration** → no significant effect on dose (less than 10%)
    - Aluminium filtration from [3,0 – 7,0] mm Al
    - Copper filtration from [0 – 0,9] mm Cu
  - **Dose at the detector** → a factor ~2 on dose
    - Beginning of 2000
      - More and more interest in radiation protection of the patient: doses at the detector reduced with around 60% compared to the first systems
      - Improvements of the detectors itself: evolution from image intensifiers to flat panel detectors
  - **Change in frame rate for image acquisition** → a factor ~2 on dose
    - 1980-1990: 50 F/S
    - 1990-2000: 30 F/s
    - > 2000: 15 F/s
Evolution of x-ray systems before year 2000:

- Beam filtration → no significant effect on dose (less than 10%)
- Dose at the detector → a factor ~2 on dose
- Change in frame rate for image acquisition → a factor ~2 on dose

For procedures performed before 2000: a **correction factor of 2 to 4** identified, depending on type of procedure

Information on working practice and type of procedures is needed
- Protective equipment, type of x-ray system, work load, ...
The ELDO project developed a dosimetry protocol for retrospective assessment of eye lens doses for interventional cardiologists

- 2 approaches, depending on available information

**Approach 1**: based on whole body doses above lead apron
- Ratio [eye lens/whole body] dose determined
- Correction factors for the use of protective equipment

**Approach 2**: based on recent eye lens dose measurements
- Detailed information needed on working practices (also for the past)
- Corrections identified for procedures performed before the year 2000

Both approaches of major interest for future epidemiological studies
- Further validation of both approaches needed

Acknowledgement: Funded by the DoReMi Network of Excellence
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