Correlation between the dose measured with eye lens dosemeters and the eye lens dose, when lead glasses are used

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Ionising radiation lead to lens opacification

**Euraloc** study results:
- Significant increase in prevalence of posterior subcapsular (PSC) lens opacities among interventional cardiologists compared to control group.
  - PSC Excess OR = 0.88 Gy⁻¹ [0.15 - 2.01]
- Linear dose-response relationship
- Indication that there is no threshold

ICRP reduced eye lens dose limit (2011):
- Need for eye lens dosimetry
- Need for leaded eyewear
Eye lens dosimetry and protection

- Protection from leaded eyewear reported on literature depends on several parameters: model, fitting of the glasses, geometry, ...

- A conservative ratio = 2 is usually considered

<table>
<thead>
<tr>
<th>Ratio between the dose without and the dose with leaded eyewear, from literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>9.9 up to 10.2&lt;sup&gt;(1)&lt;/sup&gt;</td>
</tr>
<tr>
<td>4.0 up to 6.2&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>5.3 up to 7.5&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>1.4 up to 9.3&lt;sup&gt;(4)&lt;/sup&gt;</td>
</tr>
<tr>
<td>1.1 up to 8.3&lt;sup&gt;(5)&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>(1) Dominiek and Brodecki, J of Radiol Prot, 2016; 36:N19-N25</sup>
<sup>(2) Hu et al, Radiat Prot Dosimetry 2017; 174:136-140</sup>
<sup>(3) McVey et al, J of Radiol Prot , 2013; 33:647-659</sup>
<sup>(4) Sturchio et al, Health Phys 2013; 104:S11-S16</sup>
<sup>(5) van Rooijen et al, Cardiovasc Interv Radiol 2014; 37:1149-1155</sup>
To compare the dose measured by dosemeters at different positions with the dose to:

- the sensitive volume of the eye lens.
- a reference dosemeter on the surface of the eye

Transversal view from the eye lens and reference dosemeter considered
Computed simulation using Monte Carlo method (MCNPX)
Representative geometry on an interventional cardiology setup:
  80 kVp, 4 mm Al + 0.9 mm Cu
  PA, LAO30, LAO90, RAO30, RAO90
Patient and operator represented by simplified mathematical phantoms
Operator phantom with detailed eye lens*, split into sensitive and insensitive regions

Methods

RPL dosemeter, optimized for $H_p(3)$

Dosemeters placed at 8 positions:
- 4 on the skin surface (blue)
- 2 shielded under the lens of the glasses (yellow)
- 2 unshielded over the lens of the glasses (red)

A reference dosemeter (green) was placed at the surface of the left eye, to mimic an experimental setup - $H_p(3)_{ref}$

2 models of lead glasses modeled: wraparound (left) and with side shielding (right)
The ratio $R$ between the dose measured with the dosemeters at each position, $H_p(3)_{dosemeter}$, and $H_{lens}$ - as well as $H_p(3)_{ref}$ - was calculated, and averaged over 5 beam projections, 2 accesses and the 2 models of lead glasses.

\[
R_{H_{lens}} = \frac{H_p(3)_{dosemeter}}{H_{lens}}
\]

\[
R_{H_p(3)} = \frac{H_p(3)_{dosemeter}}{H_p(3)_{ref}}
\]
Results – $R_{Hlens}$: unshielded dosemeters

- $R_{Hlens}$ for the unshielded dosemeters on the forehead and over the lens of the glasses varied from 1.0 up to 1.6.

<table>
<thead>
<tr>
<th>Position</th>
<th>$R_{Hlens}$</th>
<th>Range</th>
<th>St. Dev. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Forehead: Left Side</td>
<td>1.0</td>
<td>0.1 – 3.2</td>
<td>75</td>
</tr>
<tr>
<td>Forehead: Middle</td>
<td>1.3</td>
<td>0.6 – 3.0</td>
<td>41</td>
</tr>
<tr>
<td>Over Lens: Left Side</td>
<td>1.5</td>
<td>1.1 – 3.4</td>
<td>35</td>
</tr>
<tr>
<td>Over Lens: Front</td>
<td>1.6</td>
<td>1.2 – 3.1</td>
<td>26</td>
</tr>
</tbody>
</table>

- Dose on the dosemeter on the left side of the forehead depends on the model of lead glasses considered.
  - Considering the lead glasses separately:
    - Wraparound: $R_{Hlens} = 1.5 \pm 34\%$
    - Side shielding: $R_{Hlens} = 0.4 \pm 55\%$
Results – $R_{H\text{\text{\text{\text{\text{\text{lens}}}}}}}$: dosemeters under the glasses

- Both dosemeters under the lens of the glasses were better shielded than the eye lens:

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<tr>
<th>Position</th>
<th>$R_{H\text{\text{\text{\text{\text{\text{lens}}}}}}}$</th>
<th>Range</th>
<th>St. Dev. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Behind the frontal lens</td>
<td>0.2</td>
<td>0.1 – 0.5</td>
<td>45</td>
</tr>
<tr>
<td>Behind the side shielding*</td>
<td>0.4</td>
<td>0.2 – 0.9</td>
<td>55</td>
</tr>
</tbody>
</table>

*position considered only in the model of lead glasses with side shielding

The dose measured in any of these positions strongly underestimates the eye lens dose and would need to be multiplied by a factor between 2.5 and 5 in order to estimate the dose to the eye lens!
Results - Comparing $R_{Hp(3)}$ and $R_{Hlens}$

$H_{p(3)}^{ref}$ was 40% lower than $H_{lens}$

- $R_{Hp(3)}$ was higher than $R_{Hlens}$ for all tested positions.
- Reference dosemeter was better protected than the eye lens

<table>
<thead>
<tr>
<th></th>
<th>$R_{Hp(3)}$</th>
<th>$R_{Hlens,sensitive}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unshielded dosemeters</td>
<td>2.2 up to 3.5</td>
<td>1.0 up to 1.6</td>
</tr>
<tr>
<td>Dosemeters under the lens of the glasses</td>
<td>0.4 up to 0.8</td>
<td>0.2 up to 0.4</td>
</tr>
</tbody>
</table>

Side view of $H_{p(3)}^{ref}$ and the eye lens, protected by the lead glasses. Red lines show the radiation scattered by the patient.
Conclusions

- The dosemeters placed **under** the lens of lead glasses **did not receive the same radiation dose as the eye lens**
  - Underestimation between 60% and 80%

- Dosemeter on the **left side** of the **forehead** is **strongly influenced** by the model of **lead glasses**

- **Experimental assessment** may **overestimate** the **protection** granted by the **lead glasses by a factor of 2**.

- The **fitting of lead glasses** on the face of the operator, as well as their **models**, can largely **influence these results**.