Radiation protection of eye lenses and brain tissue of interventional cardiologists

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Radiosensitivity is related to reproductive activity of a tissue (Bergonié and Tribondeau, 1906)

- **Eye lens:** high radiosensitivity
  - even more radiosensitive than previously accepted

- **Brain:** low radiosensitivity
  - but perhaps not as low as currently assumed

*Both tissues of interventional cardiologists have been of interest in recent years*
Eye lenses: radiation induced cataracts

- Germinative cells are located in the front layer and equatorial regions of the lens
- When irradiated, they fail to differentiate properly into lens fibers
- These cells, then, migrate to the posterior region of the lenses, leading to posterior subcapsular cataract (PSC)
- 3x more common in interventional cardiologists than in unexposed individuals*

ICRP Publication 60 (1990)

- Threshold:
  - Visual impairment:
    - Single exposure: 5 Gy
    - Fractionated exposure: > 8 Gy
  - Detectable opacities:
    - Single exposure: 0.5 – 2.0 Gy
    - Fractionated exposure: 5 Gy

- Annual dose limit: 150 mSv

*Short follow up period!*
ICRP Publication 103 (2007)

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- Annual dose limit: 150 mSv

Same values were kept - **Possibility** for higher radiosensitivity was indicated

*Longer* follow up period!
ICRP Statement on Tissue Reactions (2011)

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- Threshold:
  - 0.5 Gy

- Annual dose limit: 20 mSv
Eye lens dose limits

- Included in the Basic Safety Standards

- Included in the 2013/59/Euratom Directive
  February 2018
Interventional Cardiology

- Interventional procedures

Average effective doses to monitored workers

- Doctors (cardiologists): 3.97 mSv
- Doctors (orthopaedists): 0.54 mSv
- Nurses: 0.70 mSv
- Others: 0.67 mSv
## Eye lens doses in interventional cardiology

<table>
<thead>
<tr>
<th>Table 1. Mean measured $\langle H_p(3) \rangle$ per procedure ± 1 s.d., number of procedures per year and estimated annual dose for physicians.</th>
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</thead>
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<td>$\langle H_p(3)/\text{proc} \rangle$ ± 1 s.d.</td>
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<tr>
<td>Phys. 1</td>
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<td>Phys. 8</td>
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<td>Phys. 9</td>
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=> Interventional cardiologists need monitoring!
Protection devices

A

B

C

D

J. Čaluk - Radiation Principles and Safety
Protection devices

Table 2. Reduction factors for various factors affecting the eye lens dose.

<table>
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<tr>
<th>Factor affecting the eye lens dose</th>
<th>Reduction factor</th>
<th>Remark</th>
<th>Way of calculation</th>
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<td>Ceiling suspended screen</td>
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<td>Measurements on phantom</td>
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<td>Ceiling suspended screen</td>
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<td>Ceiling suspended screen</td>
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<td>With the assumption that the screen is not always used throughout the procedure</td>
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<td>Kuon et al (2003)</td>
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## Protection devices

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<td>Fluoroscopy, cine cardiac imaging and digital subtraction angiography</td>
<td>Measurements with phantoms</td>
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<td>Lead glasses</td>
<td>10</td>
<td>Various thicknesses of glasses, and positions of the operator</td>
<td>Simulations</td>
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How to assess the eye lens dose?

- Dose reduction with lead glasses varies with several parameters
- Dosemeters available are big and not practical

How to assess the eye lens dose?

- Dose reduction with lead glasses varies with several parameters
- Dosemeters available are big and not practical
- Influence of the dosemeter’s position?

- Wraparound and flat lenses
- Beam projections
- Access
- Orientation of the head

Position of the dosemeter

- Best correlation with the dose to the eye lenses
- Higher overestimation

Position of the dosemeter

- Best correlation with the dose to the eye lenses

- Dosemeters are not as shielded as the eye lenses

Radiosensitivity is related to reproductive activity of a tissue (Bergonié and Tribondeau, 1906)

Eye lens: high radiosensitivity
- even more radiosensitive than previously accepted

Brain: low radiosensitivity
- but perhaps not as low as currently assumed

Both tissues of interventional cardiologists have been of interest in recent years
Radiosensitivity: brain

- **Low radiosensitivity**
  - **Children** - radiotherapy:
    - mean dose 1.5 Gy -> relative risk for glioma = 2.6\(^1\)
  - **Adults** - atomic bomb survivors
    - 0.3 – 0.6 Gy -> **no incidence** of tumors in the nervous system\(^1\)

\(^1\) Inskip et al Epidemiol. Rev (1995), 382-414
http://radsurg.health.ufl.edu/patients/understanding-radiosurgery.shtml
Radiosensitivity: brain

- ICRP Publication 103 (2007)
  Cancer risk to the brain perceived as higher than before: $w_T = 0.01$

- Radiologic technologists$^1$
  Brain cancer mortality: ~ 2 fold increase
    Small cohort: 26 individuals exposed

- Workers at uranium processing plant$^2$
  30% higher mortality caused by brain tumor

$^1$Rajamaran et al., Am J Roentgenol 2016;1101-1109
$^2$Dupree-Ellis et al., Am J Epidemiol 2000;91-95
Radiosensitivity: brain

Brain and Neck Tumors Among Physicians Performing Interventional Procedures

Ariel Roguin, MD, PhD\textsuperscript{a},\textsuperscript{*}, Jacob Goldstein, MD\textsuperscript{b}, Olivier Bar, MD\textsuperscript{c}, and James A. Goldstein, MD\textsuperscript{d}

- 31 case-report of brain tumor
- 22 were on the left side (85%)
Brain: protection devices

http://www.pnwx.com/Accessories/LeadProducts/Caps/
Efficiency of protection devices in reducing the brain dose

Efficiency of protection devices in reducing the brain dose

Different beam projections, brachial access

Images replicated from EuroIntervention, submitted 22/08/2017, currently still under review, Silva et al, Effect of protective devices in the radiation dose received by the brain of interventional cardiologists, Copyright (2017), with permission from Europa Digital & Publishing.
Efficiency of protection devices in reducing the brain dose

- Ceiling suspended screen were the most efficient device
  > 70% reduction of the brain dose

- Protection of lead caps strongly depends on their shape

- Lead glasses can reduce the dose in the brain by about 10% (no difference between wraparound or flat lenses)
Ceiling suspended screen

- Distance from the patient decreases its efficiency, specially in PA projection
- Large suspended ceiling screens offer slightly better protection than small ones (~10%)
Lead caps

Major source of radiation to the medical staff: *patient*
Lead caps

**Dose reduction: Brain**

- $D_R = 10\%$
- $D_R = 60\%$
- $D_R = 35\%$

**Dose reduction: Dosemeters**

- $D_R = 74\%$
- $D_R = 91\%$
- $D_R = 88\%$
Summary

- Eye lens
  A small dosimeter placed close to the bridge of the glasses has the best correlation with the eye lens dose

- Brain
  - Ceiling suspended screen offer the best protection
  - Efficiency of lead caps depends on their shape
  - Dosemeters under the cap are better shielded than the brain
Thanks for your attention!

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