Radiation protection of eye lenses and brain tissue of interventional cardiologists

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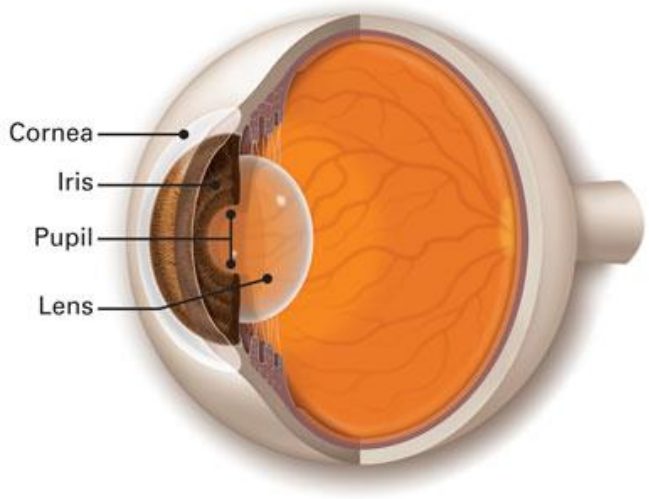
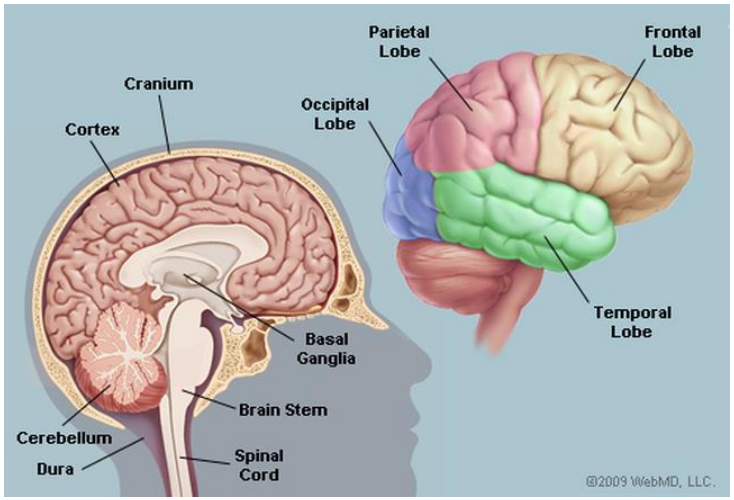
Radiosensitivity

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





Eye lens: high radiosensitivity

-> even more radiosensitive than previously accepted

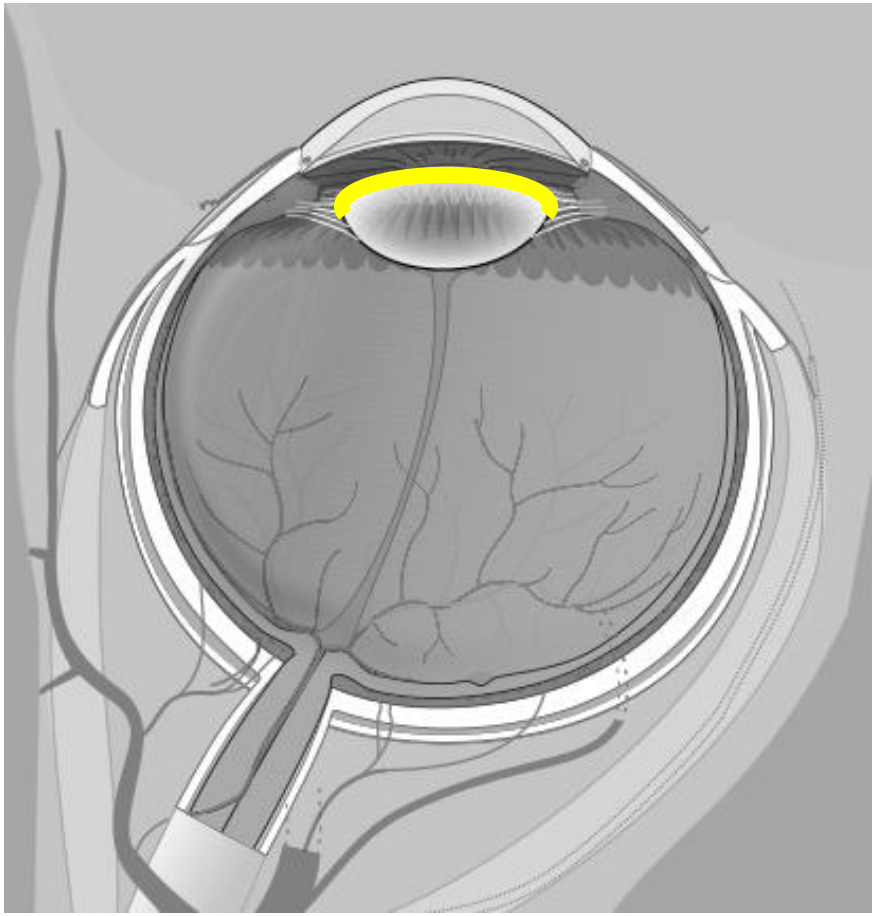
Brain: low radiosensitivity

-> but perhaps not as low as currently assumed

Both tissues of interventional cardiologists have been of interest in recent years

https://www.aao.org/eye-health/anatomy/lens-9
http://www.webmd.com/brain/picture-of-the-brain#1

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*

*Jacob, *et al* - Int J Cardiol. 2013;167:1843–7

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

-Atomic bomb survivors
-Patients treated with X or γ rays

***Short** follow up period!*

ICRP Publication **103** (2007)

- 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

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

***Longer** follow up period!*

ICRP Statement on Tissue Reactions (2011)

- Threshold:
  - Visual impairment:
    - Single exposure: [illegible]
    - Fractionated exposure: > 8 Gy
  - Detectable opacities:
    - Single exposure: > 2,0 Gy
    - Fractionated exposure: 5 Gy
- Annual dose limit: 150 mSv

- Threshold:
  - 0,5 Gy
- Annual dose limit: 20 mSv

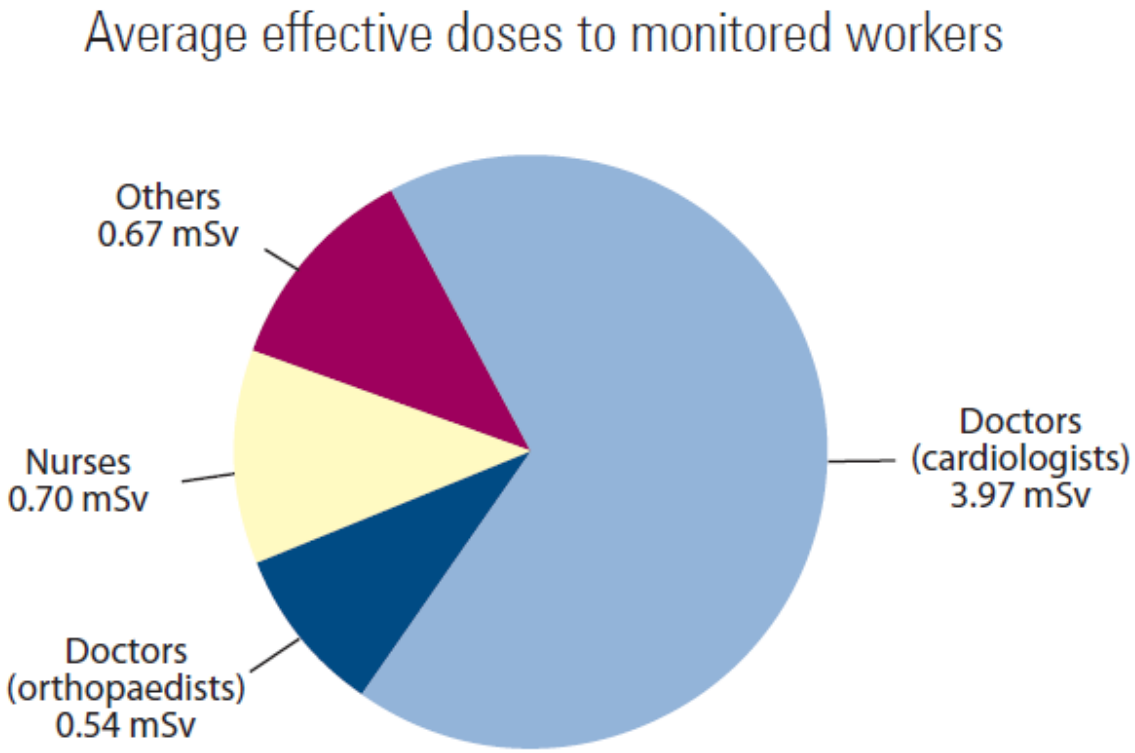
Eye lens dose limits

- Included in the Basic Safety Standards

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

Interventional Cardiology

- Interventional procedures



Eye lens doses in interventional cardiology

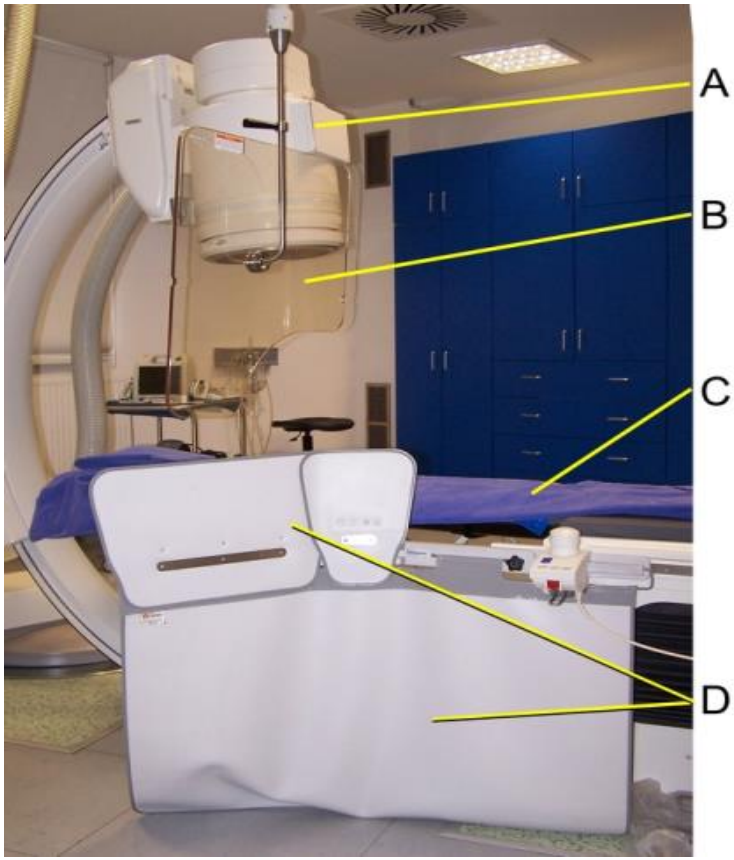
Table 1. Mean measured $H_p(3)$ per procedure ± 1 s.d., number of procedures per year and estimated annual dose for physicians.

	$<H_p(3)/\text{proc}> \pm 1$ s.d. in μSv	No. proc y^{-1}	$H_p(3)\ y^{-1}$ in mSv
Phys. 1	164 ± 129	369	61
Phys. 2	42 ± 39	303	13
Phys. 3	218 ± 163	149	32
Phys. 4	62 ± 45	253	16
Phys. 5	45 ± 42	182	8
Phys. 6	49 ± 46	253	12
Phys. 7	65 ± 53	325	21
Phys. 8	251 ± 187	77	19
Phys. 9	130 ± 102	385	50

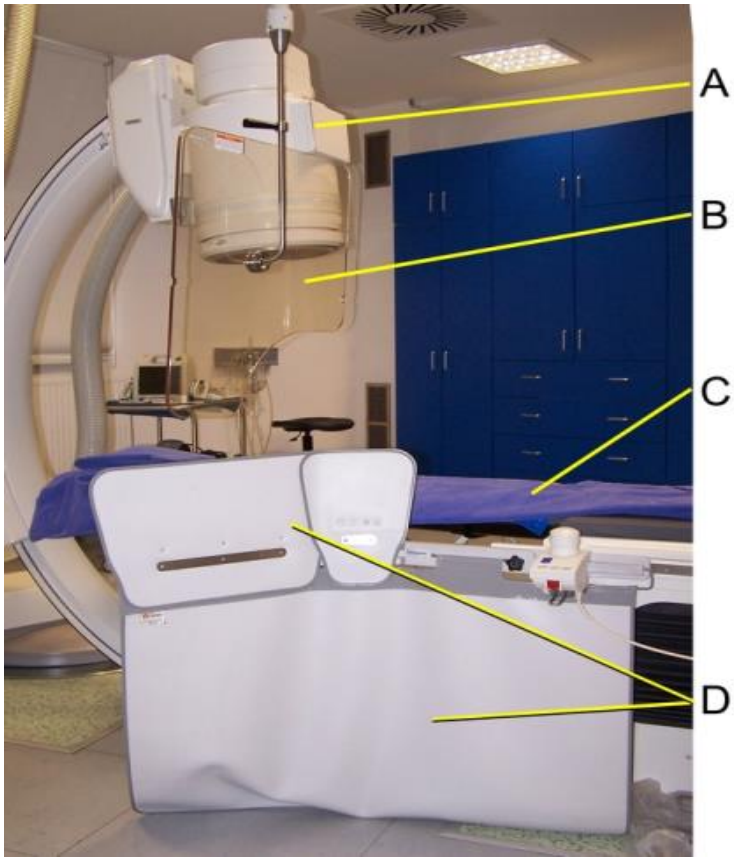
=> Interventional cardiologists need monitoring!

Principi et al. Radiat Prot Dosimetry 2015; 165:289-293

Protection devices



Protection devices



J. Radiol. Prot. **35** (2015) R17 E Carinou *et al*

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

Factor affecting the eye lens dose	Reduction factor	Remark	Way of calculation	Reference
Ceiling suspended screen	5.7		Measurements on phantom	van Rooijen *et al* (2014)
Ceiling suspended screen	2.3	Average of 25 setups	Simulations	Koukorava *et al* (2014)
Ceiling suspended screen	3		Measurements on operators	Vañó *et al* (1998)
Ceiling suspended screen	1.3–14	Depending on beam angle and position of the shield	Simulations	Koukorava *et al* (2011)
Ceiling suspended screen	30	Depending on tube orientation	Measurements with phantoms	Galster *et al* (2013)
Ceiling suspended screen	33	With the assumption that the screen is not always used throughout the procedure	Measurements with phantoms	Vano *et al* (2008)
Ceiling suspended screen	20	Depending on angle of incidence and body height	Measurements (Scatter entrance skin air kerma to the operator position)	Kuon *et al* (2003)
Ceiling suspended screen	1.5–4		Measurements	Vanhavere *et al* (2011)
Ceiling suspended screen	2–7		Measurements and simulations	Carinou *et al* (2011)

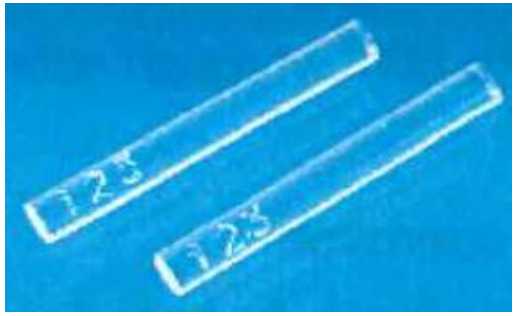
Protection devices

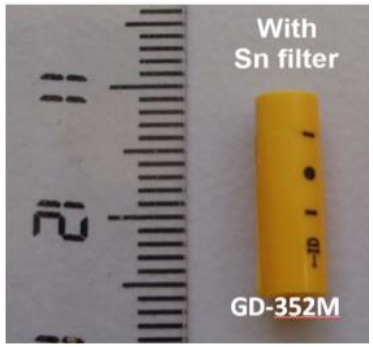
Table 2. Reduction factors for various factors affecting the eye lens dose.

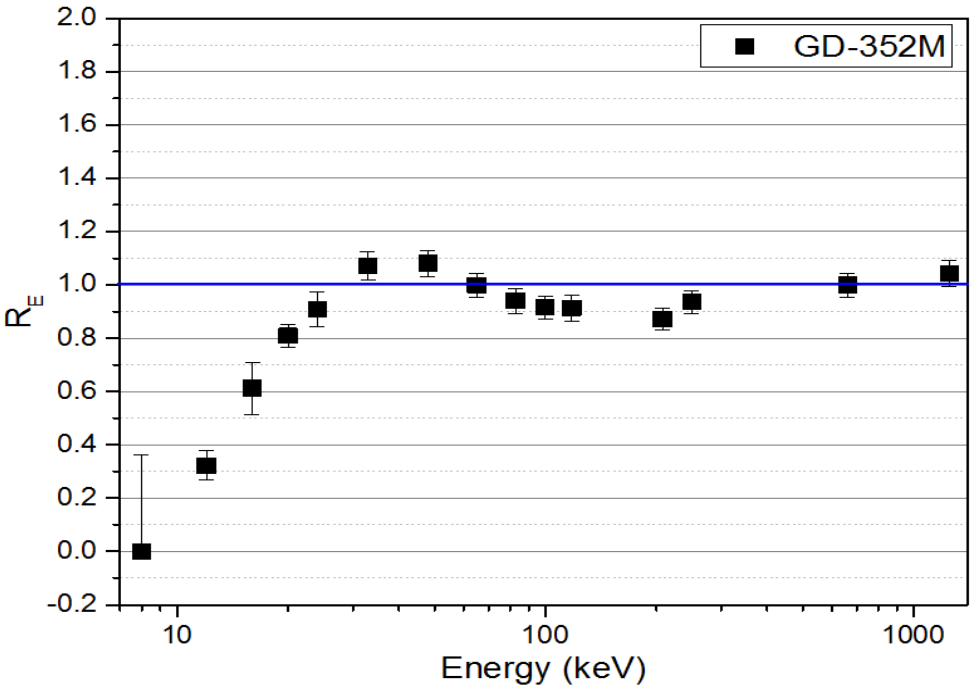
Factor affecting the eye lens dose	Reduction factor	Remark	Way of calculation	Reference
Lead glasses	5		Measurements on phantom and simulations	McVey *et al* (2013)
Lead glasses	8–10	Depending on the orientation of the operator's head and type of glasses	Measurements on phantom	Van Rooijen *et al* (2014)
Lead glasses	5–10	Depending on the position of the operator and beam angulation.	Measurements on phantom	Thornton *et al* (2010)
Lead glasses	8		Measurements	Moore *et al* (1980)
Lead glasses	8–10		Measurements	Vanhavere *et al* (2011)
Lead glasses	33	Fluoroscopy, cine cardiac imaging and digital subtraction angiography	Measurements with phantoms	Vano *et al* (2008)
Lead glasses	10	Various thicknesses of glasses, and positions of the operator	Simulations	Koukorava *et al* (2014)

How to assess the eye lens dose?

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







Energy dependence of GD-352M, in terms of $H_p(3)$ (ISO 4037 N-series)

Silva, E. H. *et. al.* Radiat Prot Dosimetry 170, p. 208-212 (2016)

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

Silva, E. H. *et. al. Radiat. Meas.* https://doi.org/10.1016/j.radmeas.2017.06.009

Position of the dosemeter

- Best correlation with the dose to the eye lenses

- Higher overestimation

Silva, E. H. *et. al. Radiat. Meas.* https://doi.org/10.1016/j.radmeas.2017.06.009

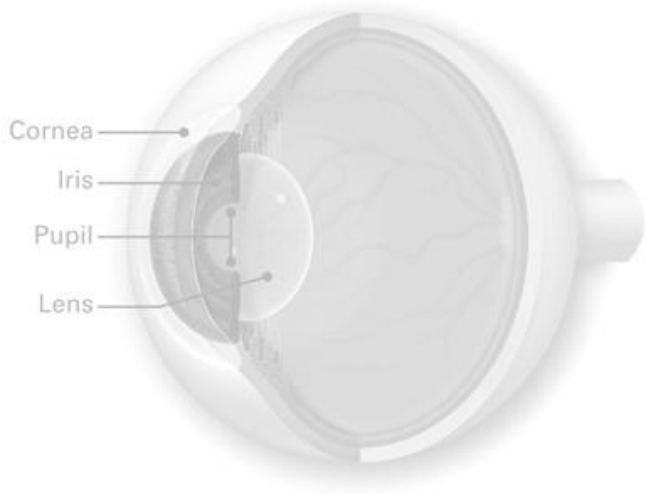
Position of the dosemeter

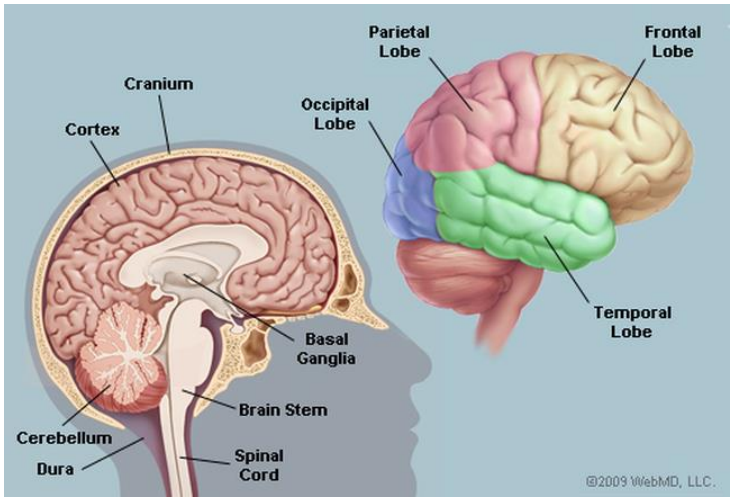
- Best correlation with the dose to the eye lenses

- Dosemeters are not as shielded as the eye lenses

Radiosensitivity: brain

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





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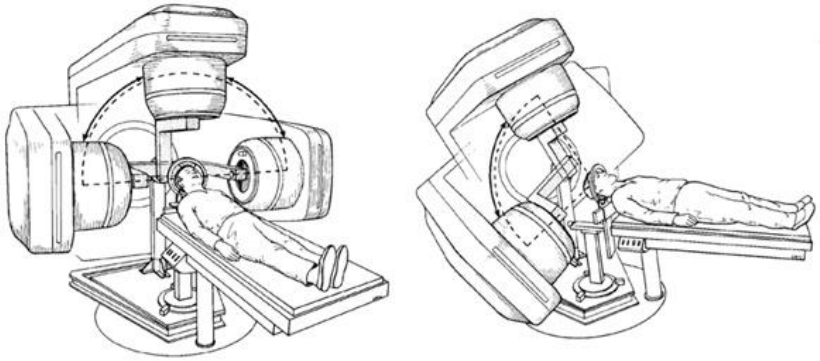
Radiosensitivity: brain

- 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

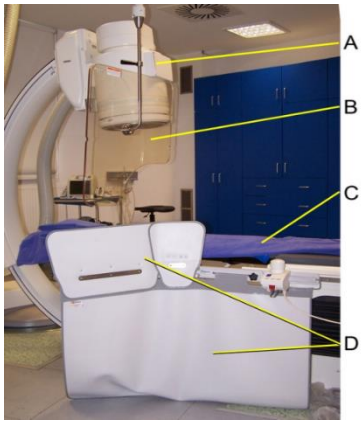
Ariel Roguin, MD, PhD[a,*], Jacob Goldstein, MD[b], Olivier Bar, MD[c], and James A. Goldstein, MD[d]

- 31 **<u>case-report</u>** of brain tumor
- 22 were on the left side (**85%**)

American Journal of Cardiology; 2013, 1368-1372

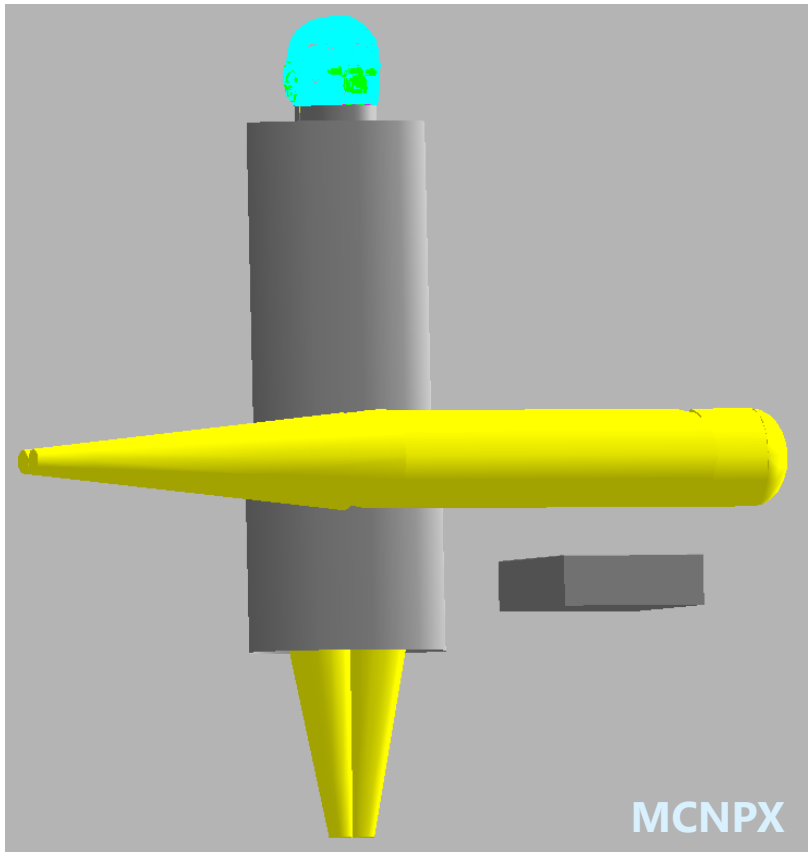
http://www.amberusa.com/dmxreadyv2/blogmanager/blogmanager.asp?post=basic_applications_c-arms

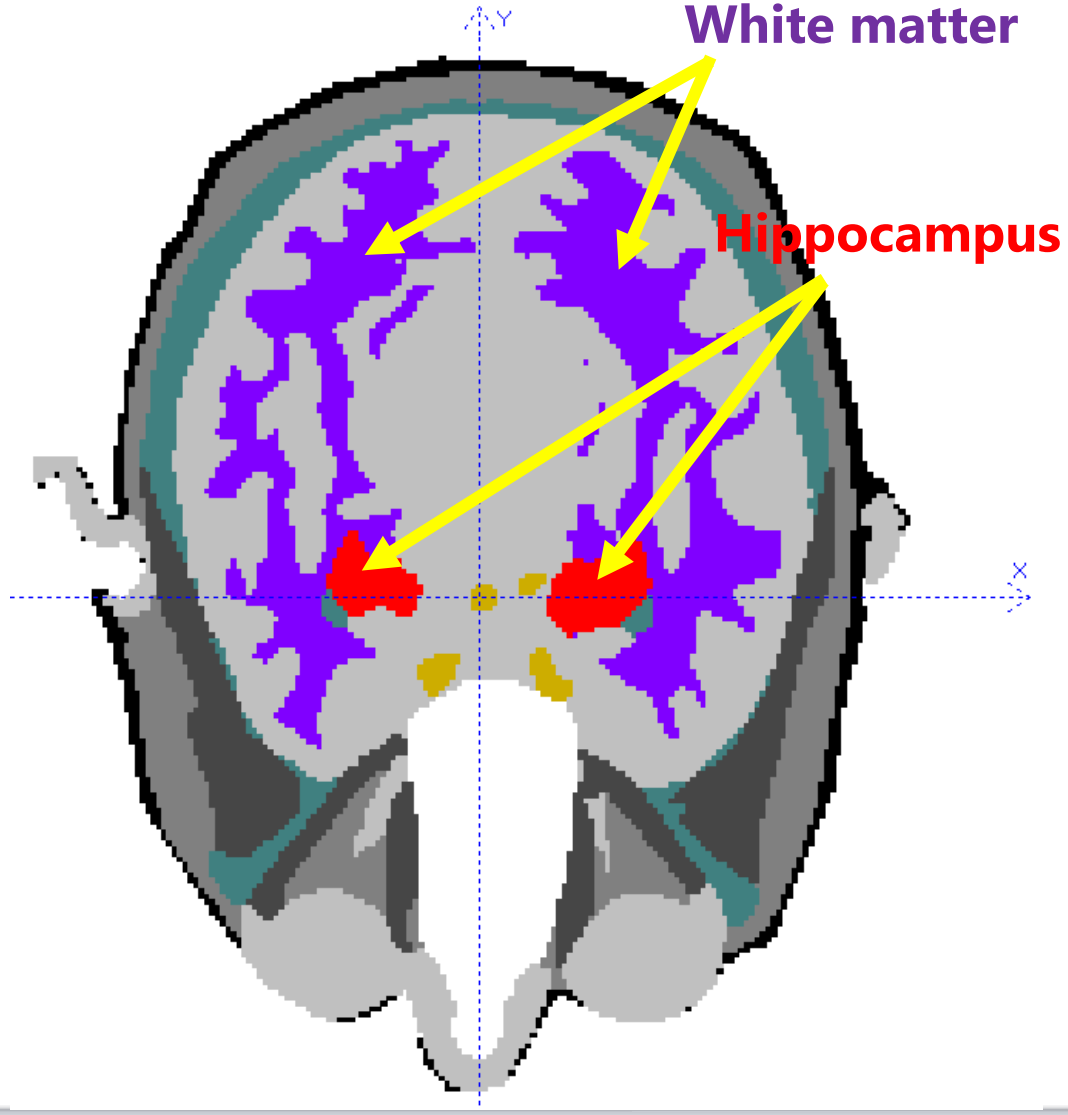
Brain: protection devices



http://www.pnwx.com/Accessories/LeadProducts/Caps/

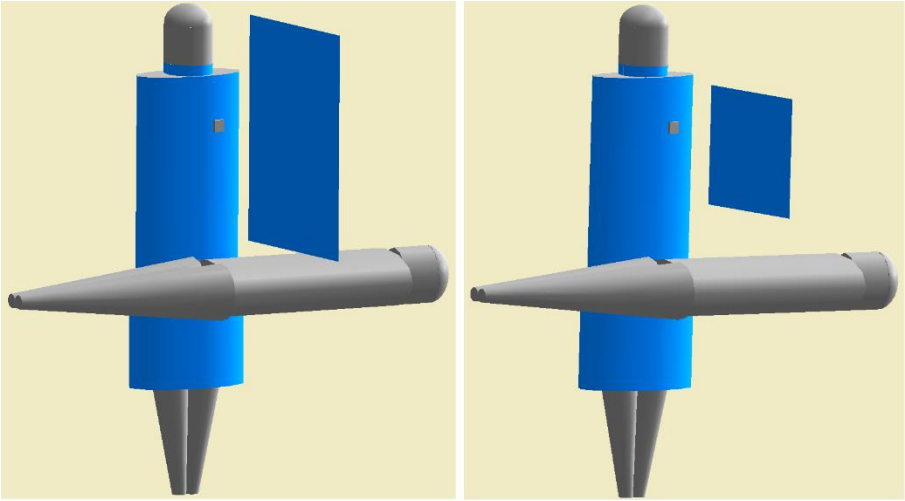
Efficiency of protection devices in reducing the brain dose





I. G. Zubal et al – Med. Phys. (1994) 21, 299-302

Efficiency of protection devices in reducing the brain dose



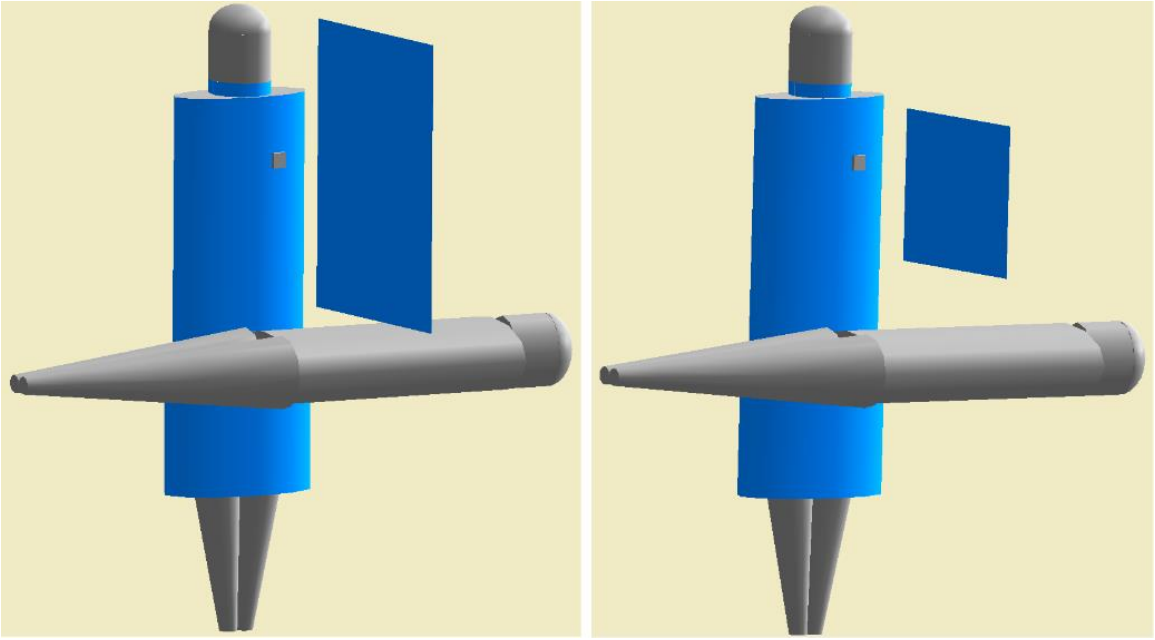
Different beam projections, brachial access

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%)

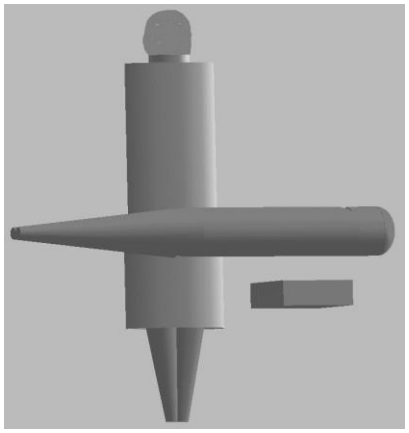
Lead caps

D_R = 10%

D_R = 60%

D_R = 35%

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



Lead caps

Dose reduction:
Brain

Dose reduction:
Dosemeters

D_R = 10%

D_R = 74%

D_R = 60%

D_R = 91%

D_R = 35%

D_R = 88%

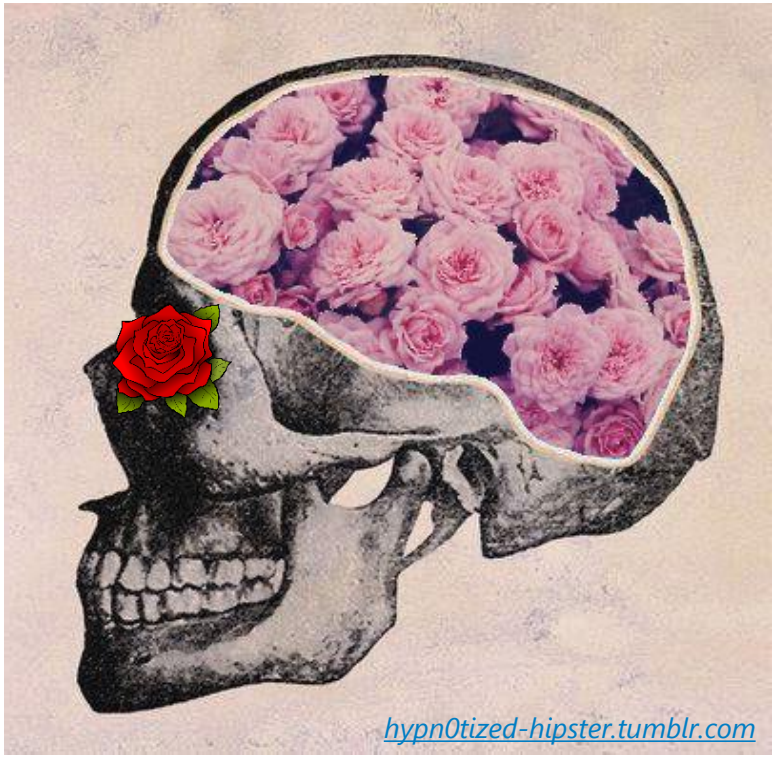
Summary

- Eye lens

  A small dosemeter 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!



Acknowledgements:

Filip Vanhavere, PhD (SCK•CEN)

Prof. Nico Buls (VUB)

Lara Struelens, PhD (SCK•CEN)

Peter Covens, PhD (VUB)