Dosimetry for medical cohorts: The eye lens

L. Struelens, P. Askounis , D. Berus, E. Carinou, O. Ciraj-Bjelac, I. Clairand, P. Covens, J. Domienik, J. Farah, R. Padovani

Lara.struelens@sckcen.be

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 <u>individual information on working history</u>
   - 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')

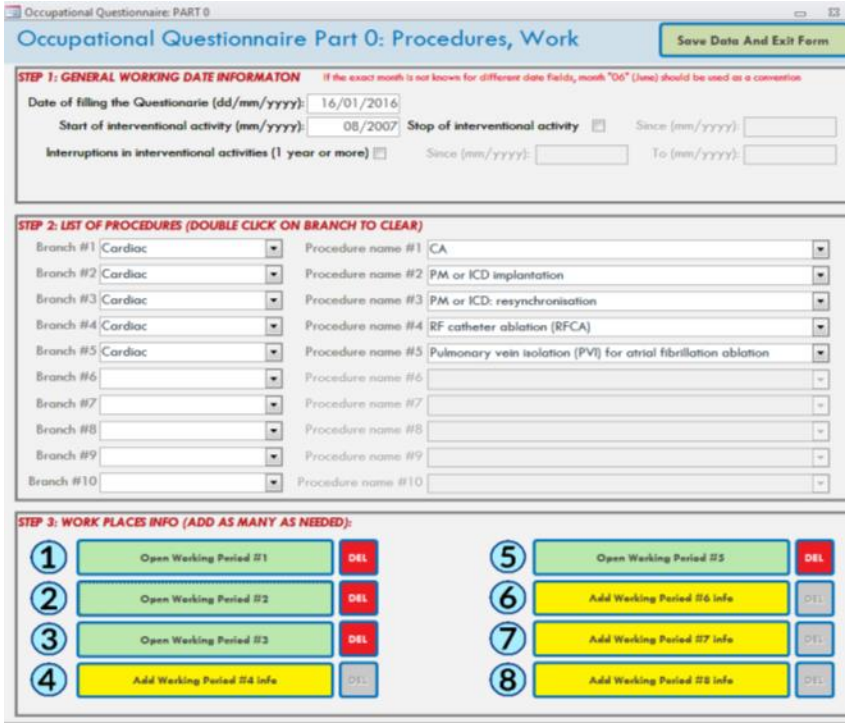
B. Based on routine <u>individual whole body dosimetry</u>
   - Conversion factors from whole body dose → eye lens dose & associated uncertainty

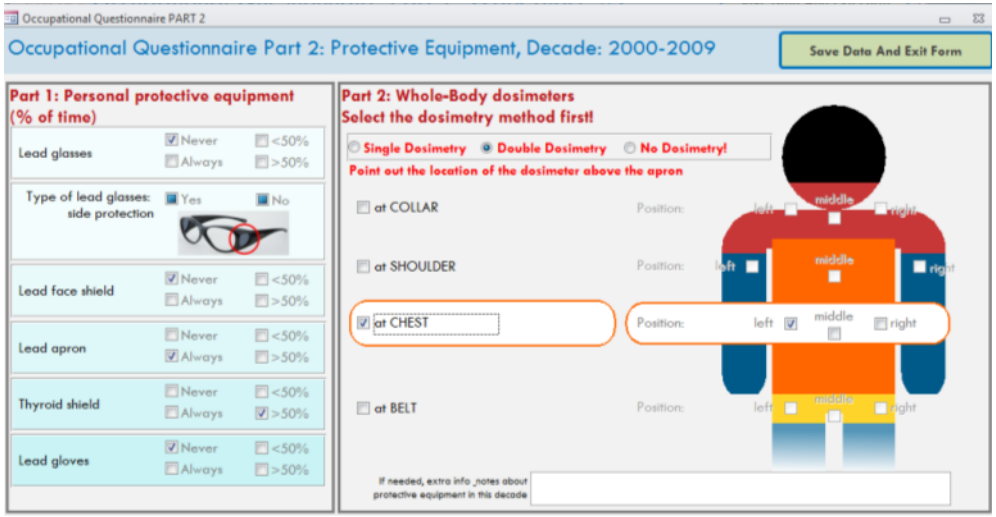
OPERA

Euraloc
European epidemiological study on radiation-induced lens opacities among interventional cardiologists

Approach 1: Information on working history

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

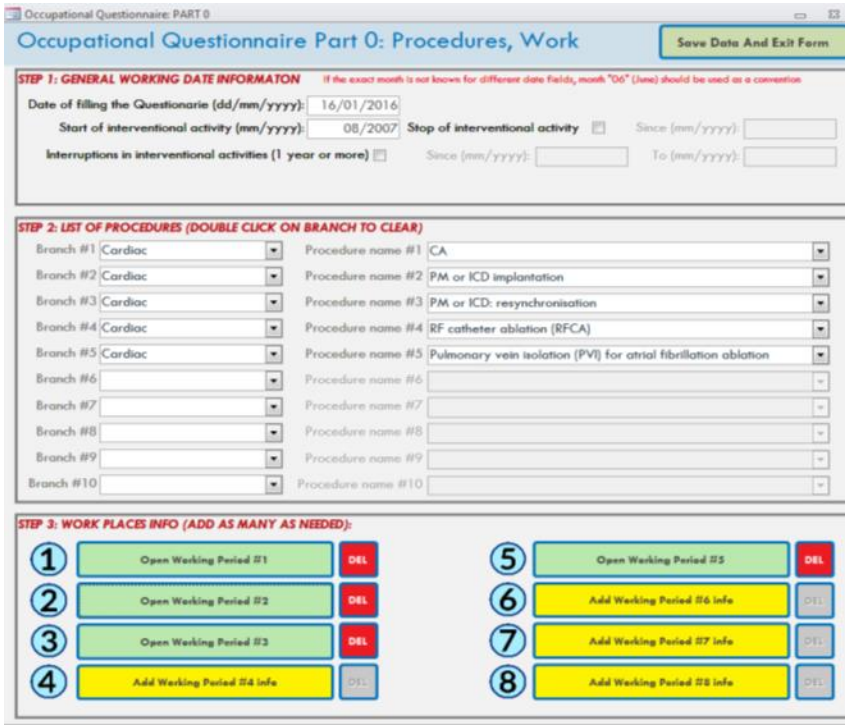


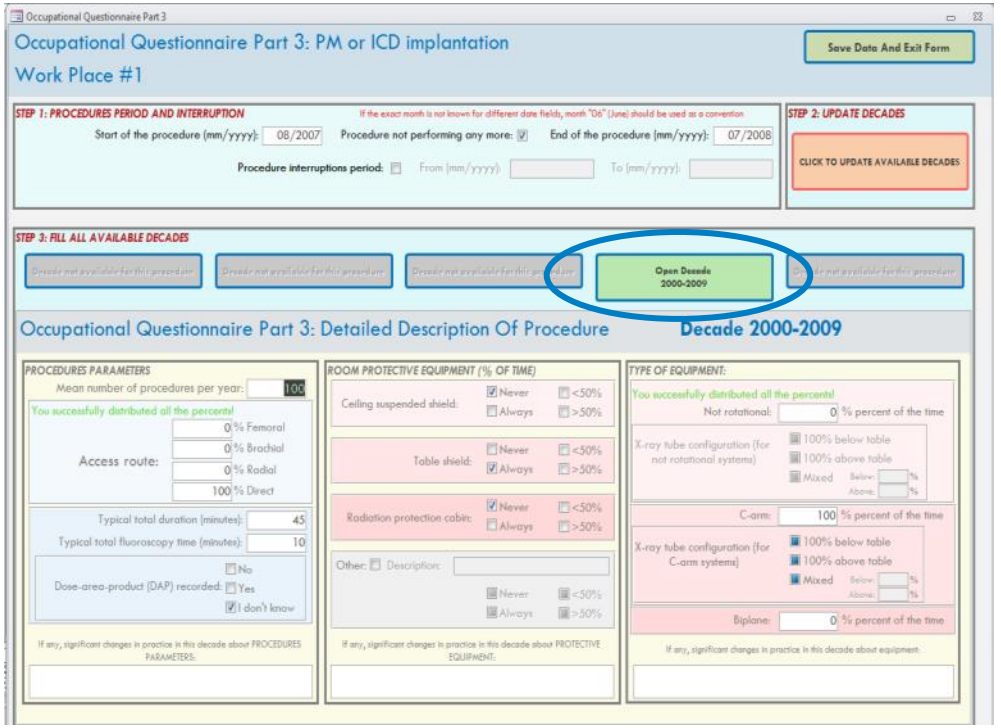


Approach 1: Information on working history

- 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





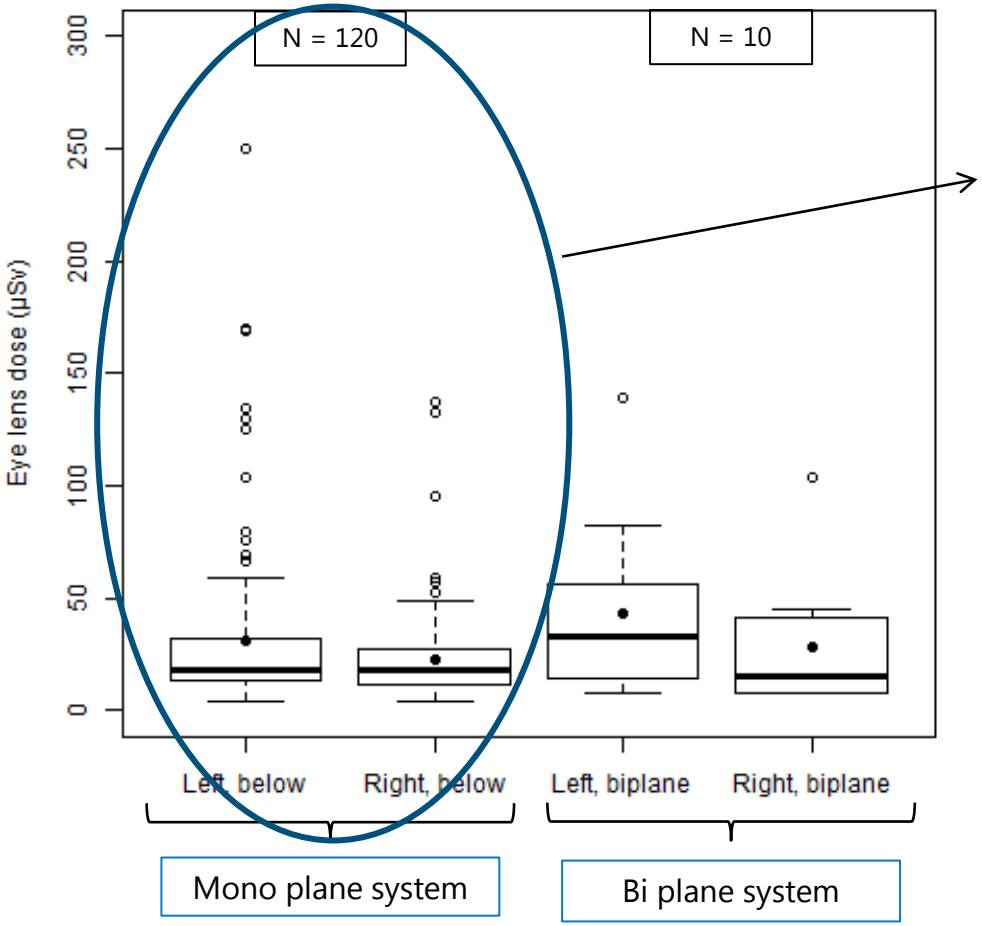
Approach 1

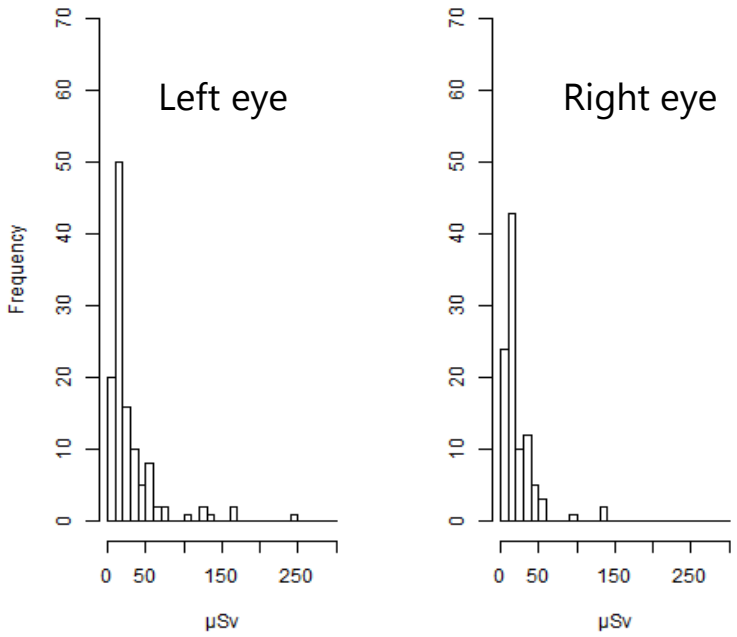
- Literature review
  - 82 papers read
    - 52% papers considered in first round
      - Eye lens dose data for interventional cardiology
      - Reduction factors of shielding (ceiling screen, lead glasses)
    - 3 additional studies with unpublished data
  - Final selection
    - Raw data from the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

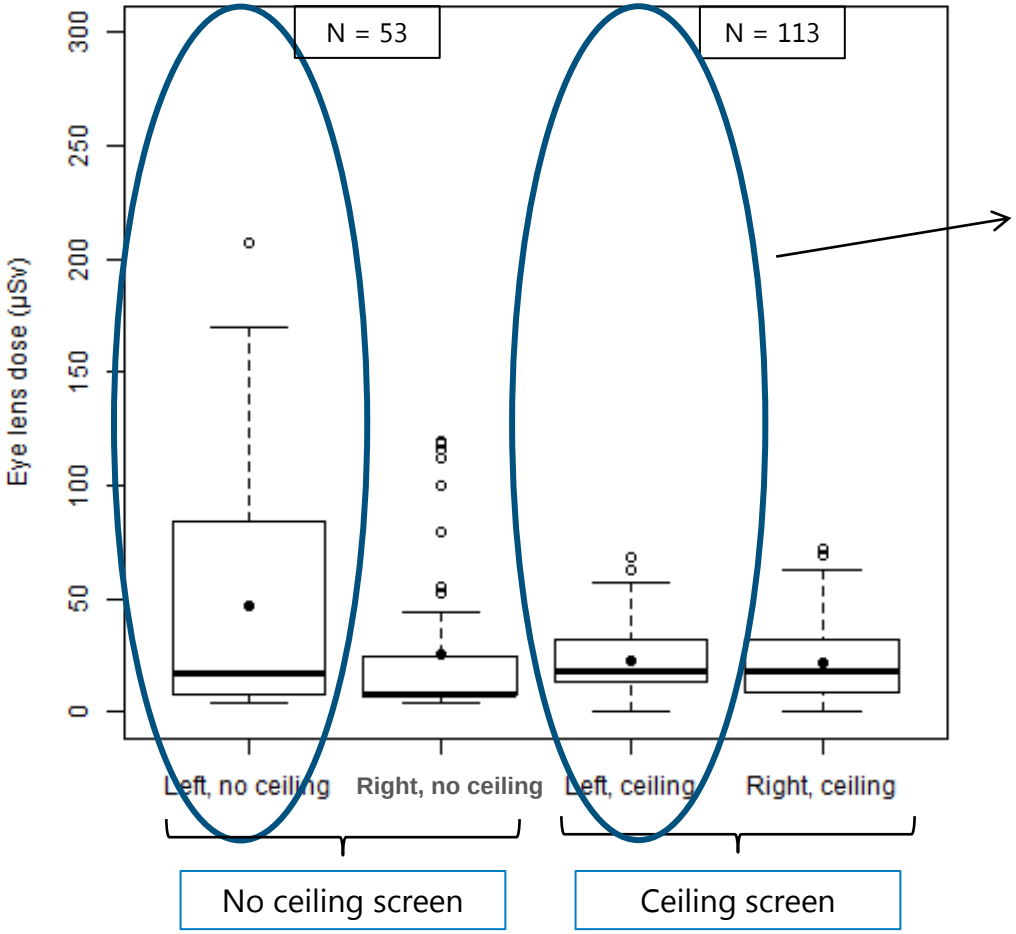
- Median dose: 18 µSv
- 95% CI [8; 135]

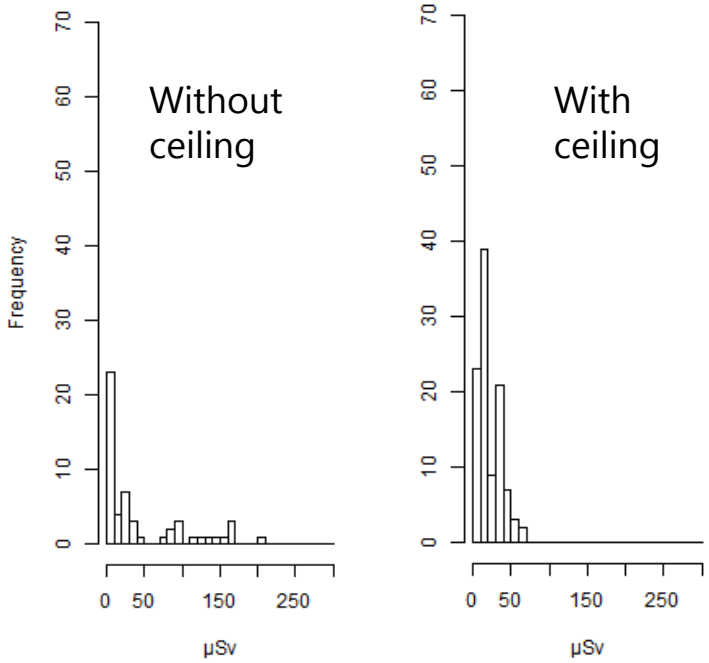
Biplane ; Left eye

- Median dose: 32 µSv
- 95% CI [8, 126]

Approach 1

- Resulting dose distributions: RF ablations ; Monoplane system





No ceiling screen ; Left eye

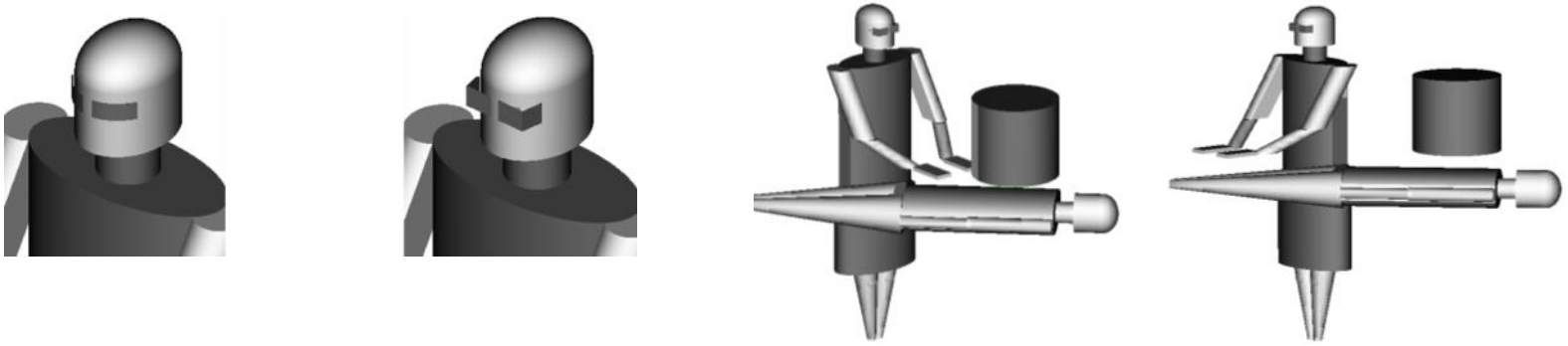
- Median dose: 17 µSv
- 95% CI [4; 169]

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

} 20 combinations

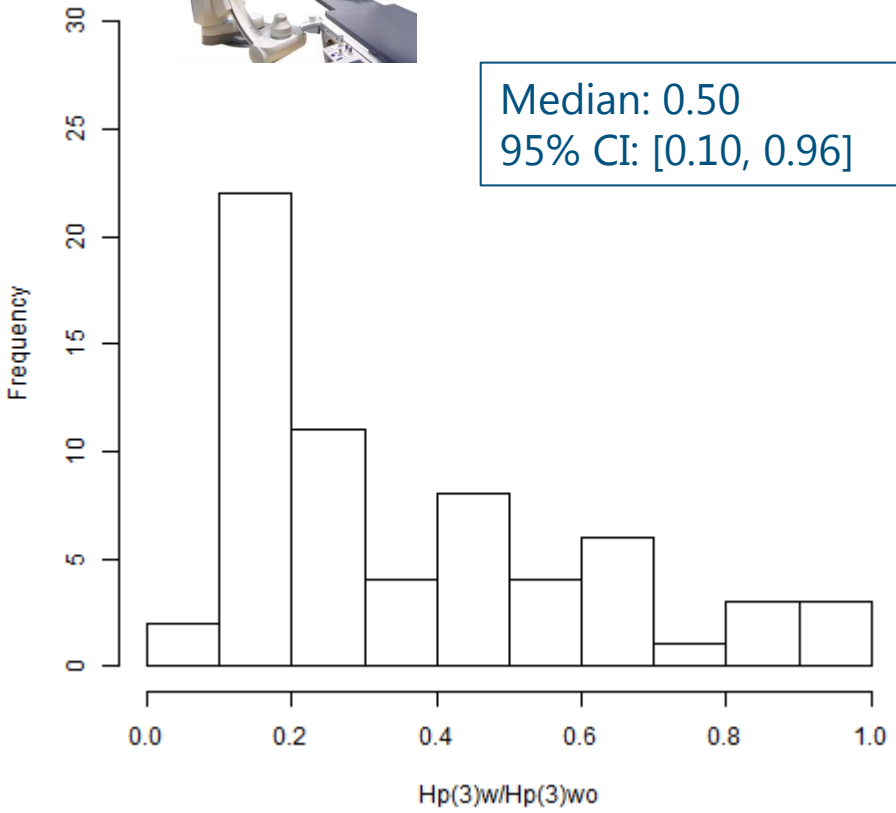
⇒ Frequency distribution of $\frac{H_p(3)_{with}}{H_p(3)_{without}}$ (→ 180 simulations)

Approach 1

- Effect of lead glasses → Monte Carlo simulations

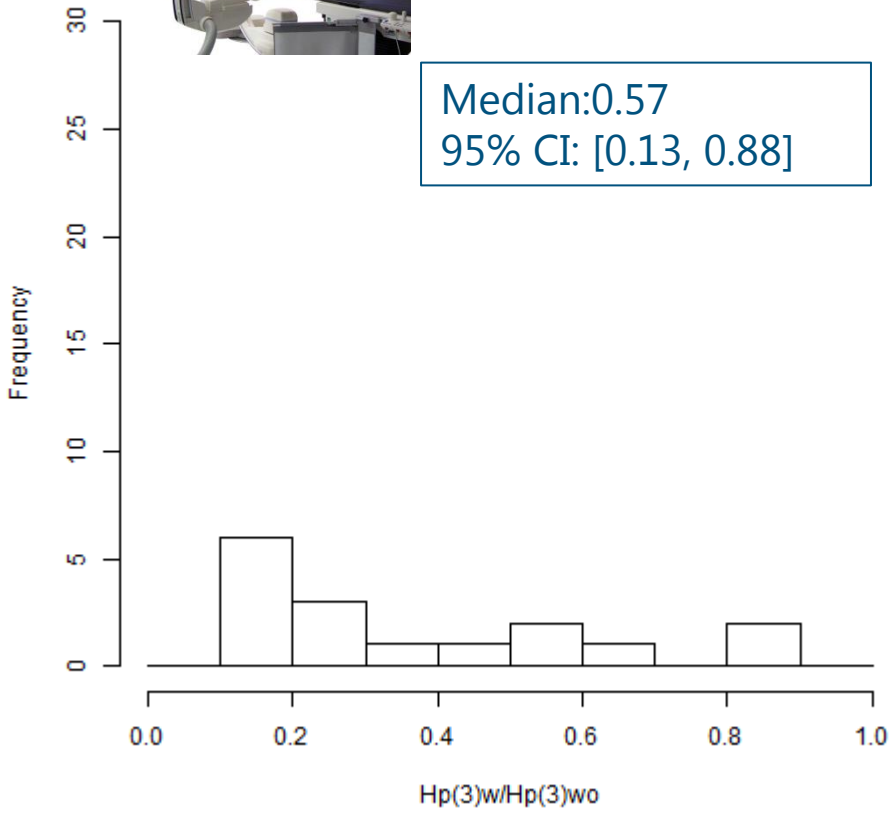
Monoplane

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



Biplane

Median:0.57
95% CI: [0.13, 0.88]



Approach 1: Summary

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

i: decades
j: type of procedure

- 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

Approach 1: Summary

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

i: decades
j: type of procedure

- 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

⇒ Applied on procedures performed before '2000
⇒ 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*)

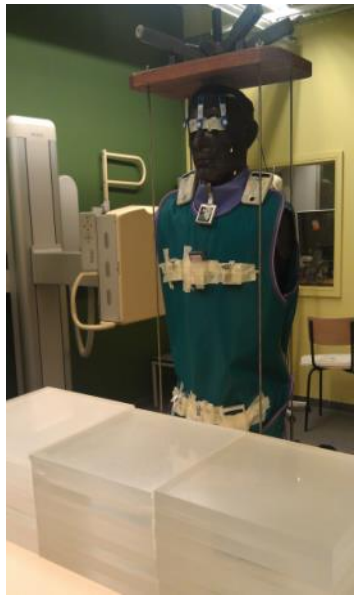
← Collected in the occupational questionnaire

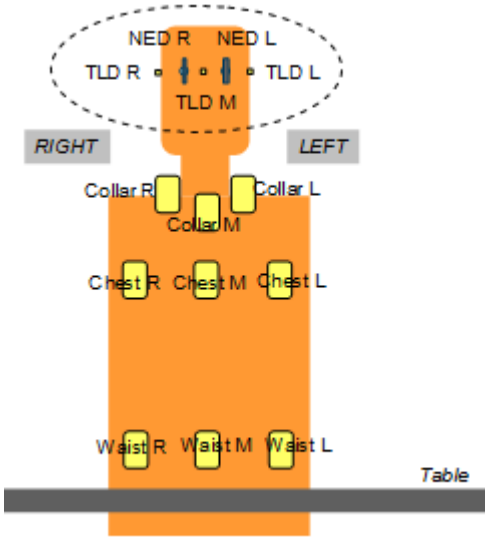
Approach 2: Conversion from whole body doses

- 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





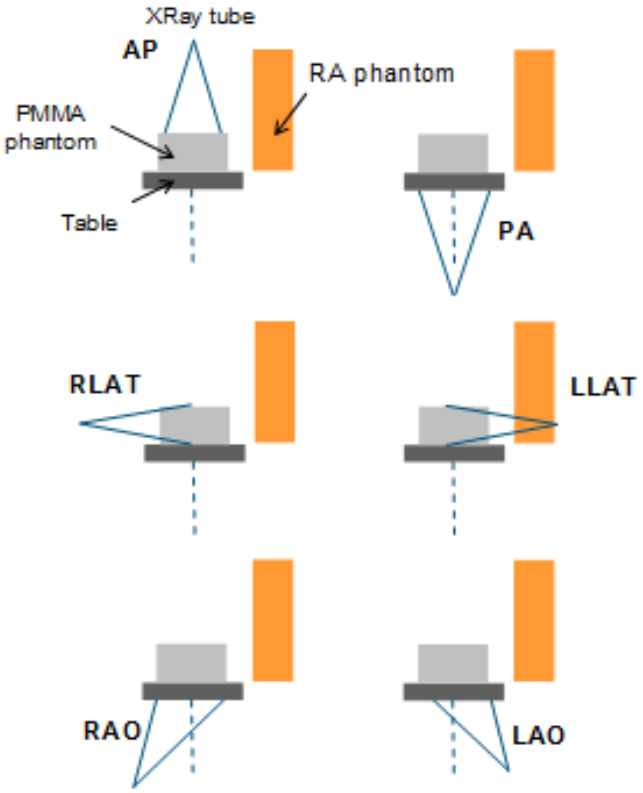
Approach 2

- 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)



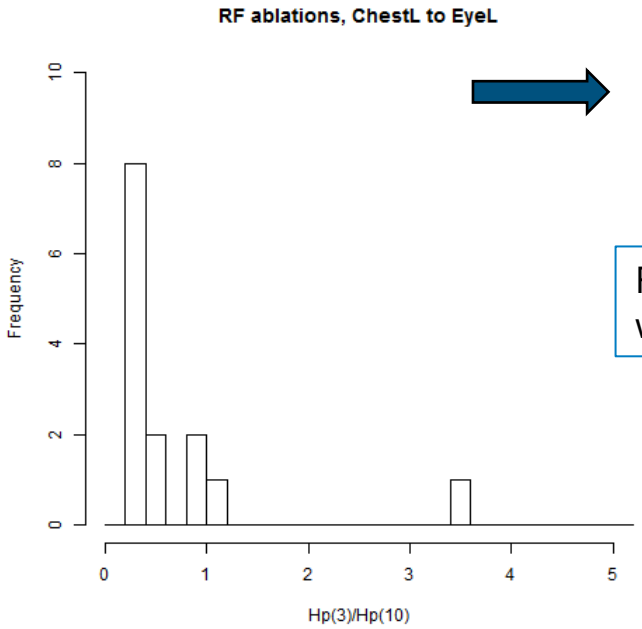
Approach 2

	Distance_Projection
1	0cm_AP
2	0cm_PA
3	0cm_RAO
4	0cm_RLAT
5	40cm_AP
6	40cm_PA
7	40cm_RAO
8	40cm_LAO
9	40cm_RLAT
10	40cm_LLAT
11	40cm_PA_LLAT
12	40cm_RAO30_LAO30
13	40cm_RAO45_LAO45
14	70cm_AP
15	70cm_PA
16	70cm_RAO
17	70cm_LAO
18	70cm_RLAT
19	70cm_LLAT
20	62cm_PA_LLAT

$H_p(3)/H_p(10)$ 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)



$$D\left[H_p(3)/H_p(10)\right]$$

For each position of the whole body dosemeter

Approach 2

- Effect of lead glasses → Monte Carlo simulations

	Distance_Projection
1	0cm_AP
2	0cm_PA
3…5	…
6	40cm_PA
7	40cm_RAO
8	40cm_LAO
9	40cm_RLAT
10	40cm_LLAT
11…19	…
20	62cm_PA_LLAT

$H_p(3)_{with}/H_p(3)_{without}$ 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 $H_p(10)$

$$\Rightarrow \left[\frac{H_p(3)}{H_p(10)}\right]_{without\ ceiling} \approx \left[\frac{H_p(3)}{H_p(10)}\right]_{with\ ceiling}$$

Approach 2: Summary

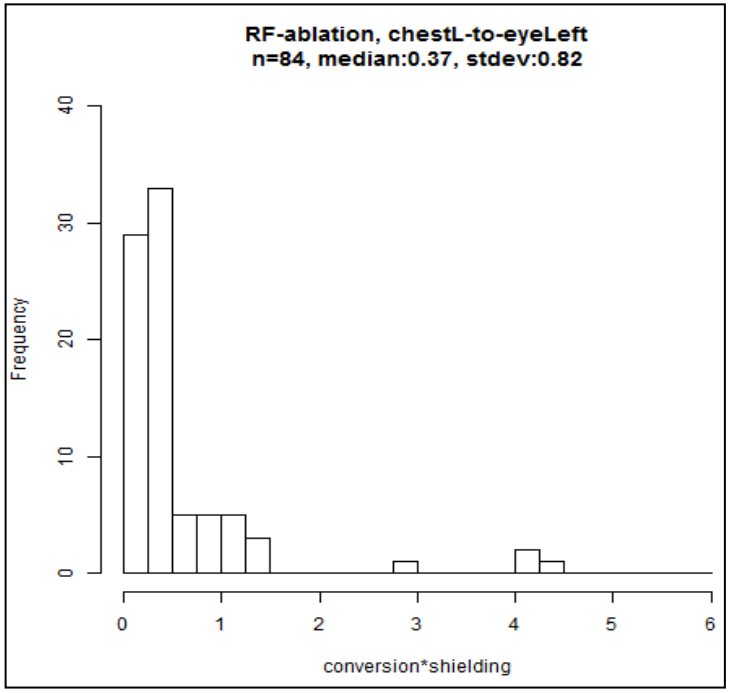
$$H_p(3)_{cum} = \sum_i \sum_j H_p(10)_{i,j} \times D\left[\frac{H_p(3)}{H_p(10)}\right]_j \times D\left[\frac{H_p(3)_{with\ glasses}}{H_p(3)_{without\ glasses}}\right]_j$$

i: year
j: type of procedure

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

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

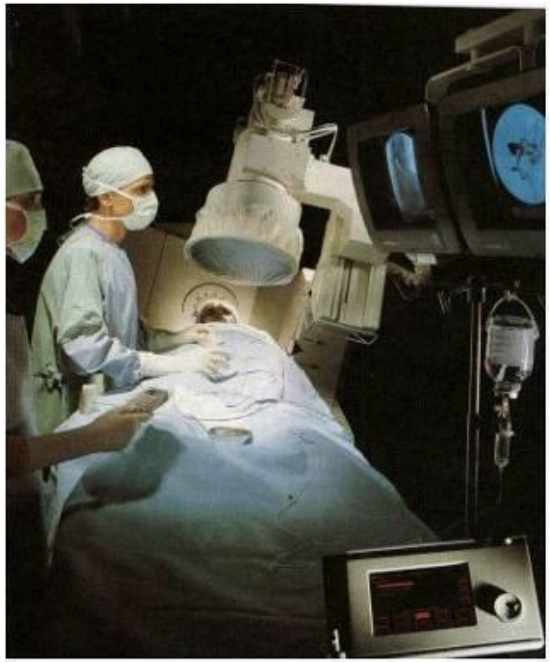
Effect of lead glasses:
Matching projection and distance



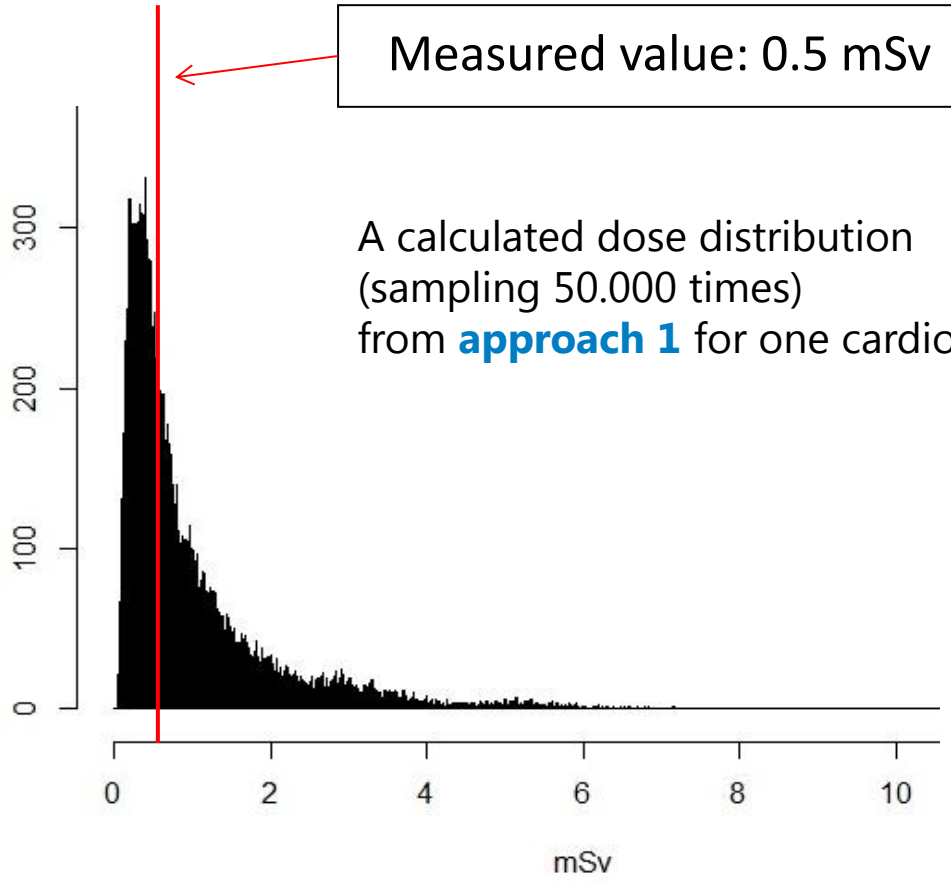
Validation of methodology

- 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

- $D_{calc,A1} \leftrightarrow D_{calc,A2} \leftrightarrow D_{meas}$



Validation of methodology



A calculated dose distribution
(sampling 50.000 times)
from **approach 1** for one cardiologist

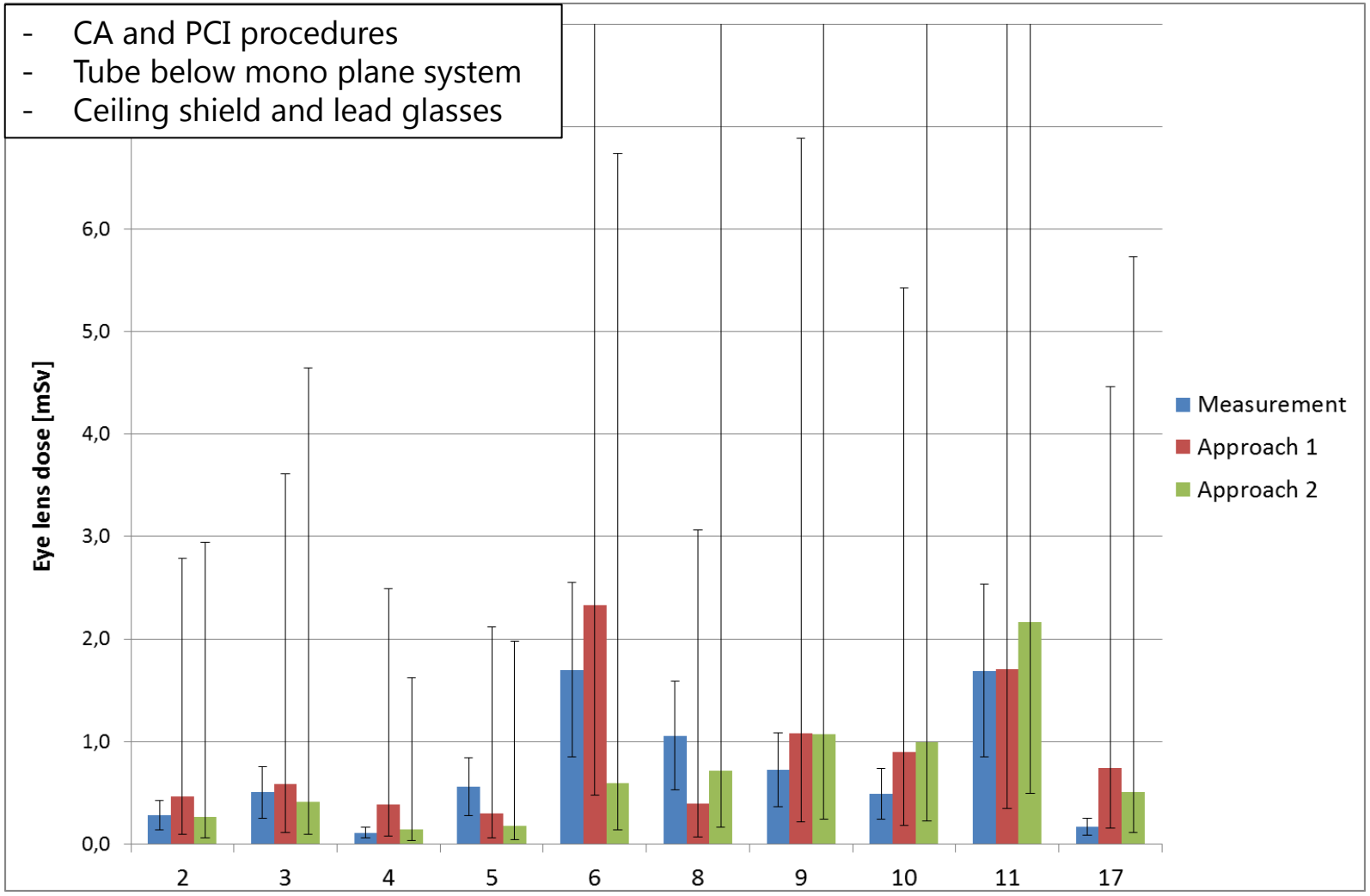
Monoplane tube below system

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

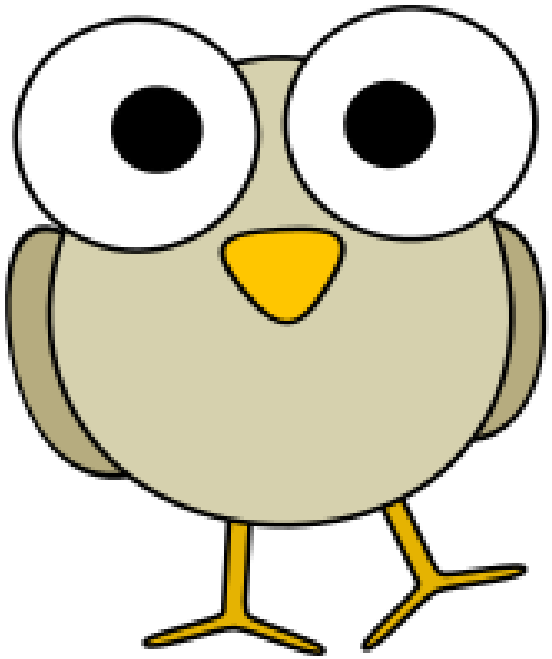


Conclusion

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

- 2 complementary approaches

Individual working history + eye lens dose data from literature	Conversion from whole body to eye lens dose
 • Direct eye lens dose measurements • Individual occupational history • Evolution over the years • Consider the number of procedures	 • 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!



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Thank you