

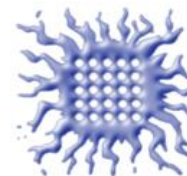
Dosimetry for medical cohorts: The eye lens

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GREEK ATOMIC ENERGY COMMISSION

- 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

- 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

- Objective:
 - 440 interventional cardiologists
 - 285 unexposed people
- } Multi-national study,
a common standardised protocol
- Two complementary dosimetric approaches
 - A. Based on individual information on working history
 - 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 individual whole body dosimetry
 - Conversion factors from **whole body dose** → **eye lens dose** & associated uncertainty

Approach 1: Information on working history

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

Occupational Questionnaire: PART 0

Occupational Questionnaire Part 0: Procedures, Work

Save Data And Exit Form

STEP 1: GENERAL WORKING DATE INFORMATION If the exact month is not known for different date fields, month "06" (June) should be used as a convention

Date of filling the Questionnaire (dd/mm/yyyy): 16/01/2016

Start of interventional activity (mm/yyyy): 08/2007 Stop of interventional activity Since (mm/yyyy):

Interruptions in interventional activities (1 year or more) Since (mm/yyyy): To (mm/yyyy):

STEP 2: LIST OF PROCEDURES (DOUBLE CLICK ON BRANCH TO CLEAR)

Branch #	Cardiac	Procedure name #	CA
Branch #1	Cardiac	Procedure name #1	CA
Branch #2	Cardiac	Procedure name #2	PM or ICD implantation
Branch #3	Cardiac	Procedure name #3	PM or ICD: resynchronisation
Branch #4	Cardiac	Procedure name #4	RF catheter ablation (RFCA)
Branch #5	Cardiac	Procedure name #5	Pulmonary vein isolation (PVI) for atrial fibrillation ablation
Branch #6		Procedure name #6	
Branch #7		Procedure name #7	
Branch #8		Procedure name #8	
Branch #9		Procedure name #9	
Branch #10		Procedure name #10	

STEP 3: WORK PLACES INFO (ADD AS MANY AS NEEDED):

1	Open Working Period #1	DEL	5	Open Working Period #5	DEL
2	Open Working Period #2	DEL	6	Add Working Period #6 info	DEL
3	Open Working Period #3	DEL	7	Add Working Period #7 info	DEL
4	Add Working Period #4 info	DEL	8	Add Working Period #8 info	DEL


Occupational Questionnaire PART 2

Occupational Questionnaire Part 2: Protective Equipment, Decade: 2000-2009

Save Data And Exit Form

Part 1: Personal protective equipment (% of time)

Lead glasses Never <50% Always >50%

Type of lead glasses: side protection Yes No 

Lead face shield Never <50% Always >50%

Lead apron Never <50% Always >50%

Thyroid shield Never <50% Always >50%

Lead gloves Never <50% Always >50%

Part 2: Whole-Body dosimeters
Select the dosimetry method first!

Single Dosimetry Double Dosimetry No Dosimetry!

Point out the location of the dosimeter above the apron


at COLLAR Position: left middle right

at SHOULDER Position: left middle right

at CHEST Position: left middle right

at BELT Position: left middle right

If needed, extra info _notes about protective equipment in this decade



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

Occupational Questionnaire Part 0: Procedures, Work

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Branch #1	Cardiac	Procedure name #1	CA
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Branch #4	Cardiac	Procedure name #4	RF catheter ablation (RFCA)
Branch #5	Cardiac	Procedure name #5	Pulmonary vein isolation (PVI) for atrial fibrillation ablation
Branch #6		Procedure name #6	
Branch #7		Procedure name #7	
Branch #8		Procedure name #8	
Branch #9		Procedure name #9	
Branch #10		Procedure name #10	

STEP 3: WORK PLACES INFO (ADD AS MANY AS NEEDED):

1	Open Working Period #1	DEL	5	Open Working Period #5	DEL
2	Open Working Period #2	DEL	6	Add Working Period #6 Info	DEL
3	Open Working Period #3	DEL	7	Add Working Period #7 Info	DEL
4	Add Working Period #4 Info	DEL	8	Add Working Period #8 Info	DEL

Occupational Questionnaire Part 3: PM or ICD implantation

Work Place #1

STEP 1: PROCEDURES PERIOD AND INTERRUPTION If the exact month is not known for different date fields, month "06" (June) should be used as a convention

Start of the procedure (mm/yyyy): 08/2007 Procedure not performing any more: End of the procedure (mm/yyyy): 07/2008

Procedure interruptions period: From (mm/yyyy): To (mm/yyyy):

STEP 2: UPDATE DECADES

CLICK TO UPDATE AVAILABLE DECADES

STEP 3: FILL ALL AVAILABLE DECADES

Open Decade 2000-2009

Occupational Questionnaire Part 3: Detailed Description Of Procedure **Decade 2000-2009**

PROCEDURES PARAMETERS

Mean number of procedures per year: 100

You successfully distributed all the percent!

Access route: 0% Femoral, 0% Brachial, 0% Radial, 100% Direct

Typical total duration (minutes): 45
Typical total fluoroscopy time (minutes): 10

Dose-area-product (DAP) recorded: No, Yes, I don't know

ROOM PROTECTIVE EQUIPMENT (% OF TIME)

Ceiling suspended shield: Never <50%, Always >50%

Table shield: Never <50%, Always >50%

Radiation protection cabinet: Never <50%, Always >50%

Other: Description:

TYPE OF EQUIPMENT:

You successfully distributed all the percent!


Not rotational: 0% percent of the time

X-ray tube configuration (for not rotational systems): 100% below table, 100% above table, Mixed

C-arm: 100% percent of the time

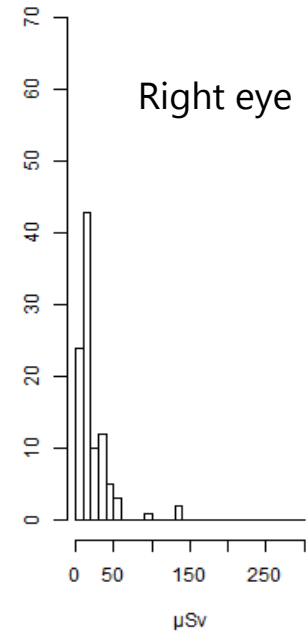
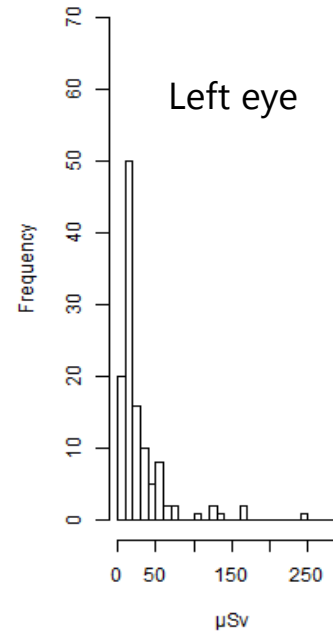
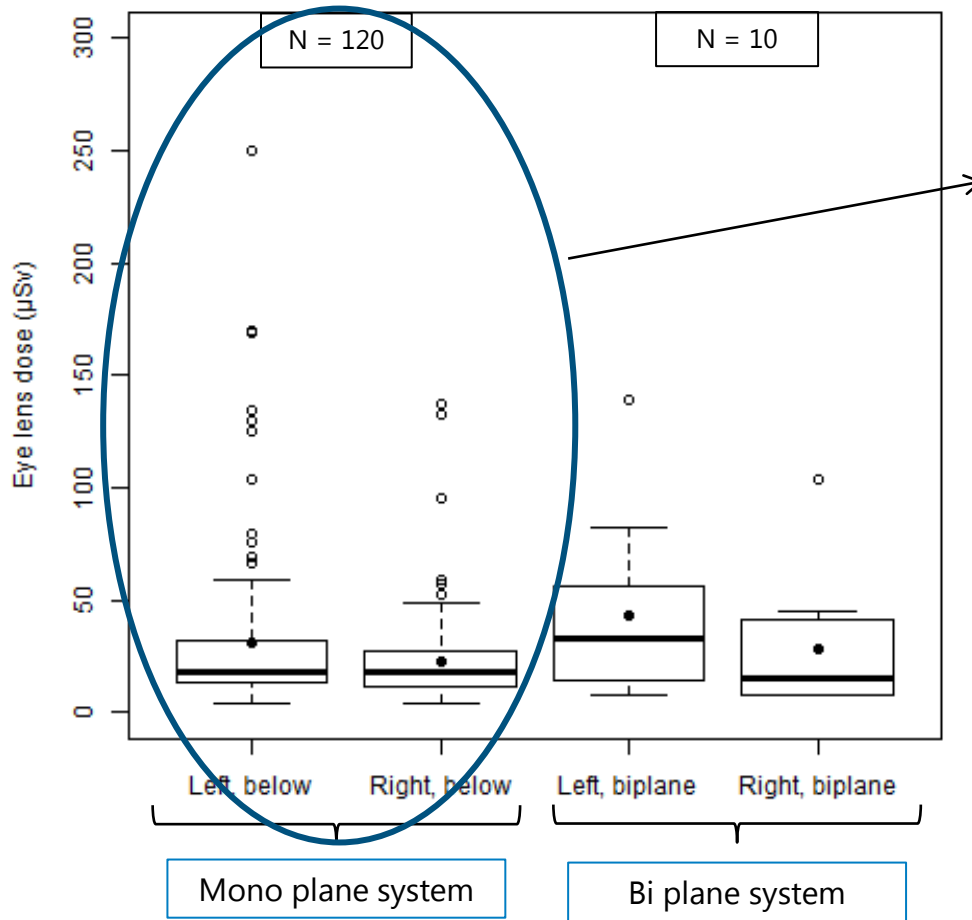
X-ray tube configuration (for C-arm systems): 100% below table, 100% above table, Mixed

Biplane: 0% percent of the time

- 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

- Resulting dose distributions: CA procedure ; with ceiling screen



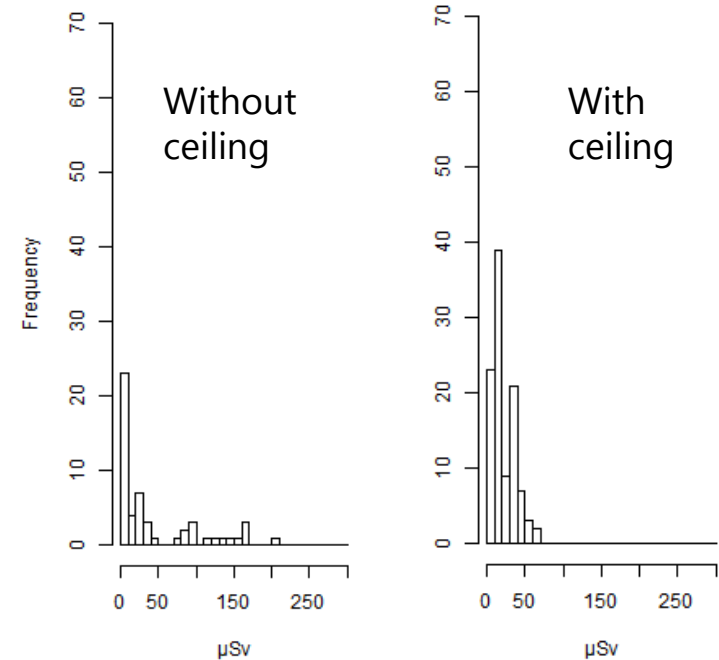
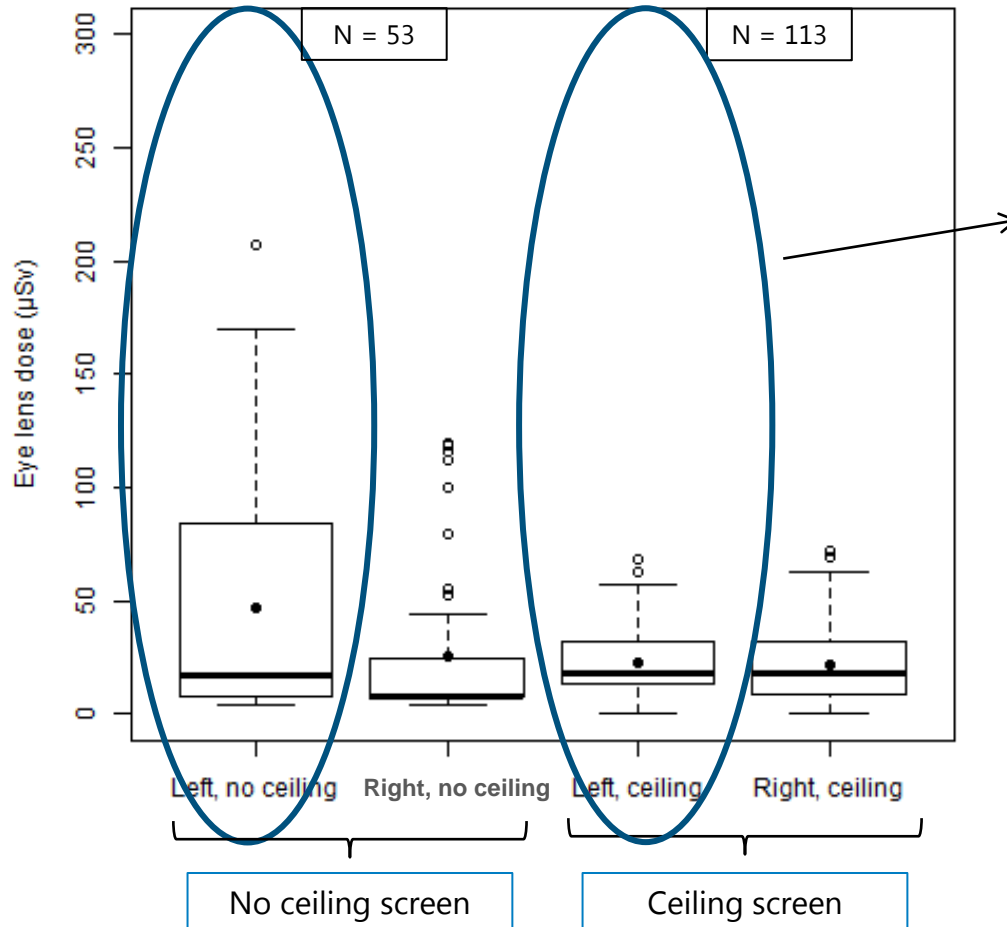
Tube below ; Left eye

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

Biplane ; Left eye

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

- Resulting dose distributions: RF ablations ; Monoplane system



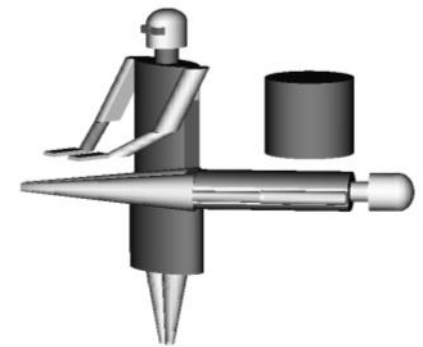
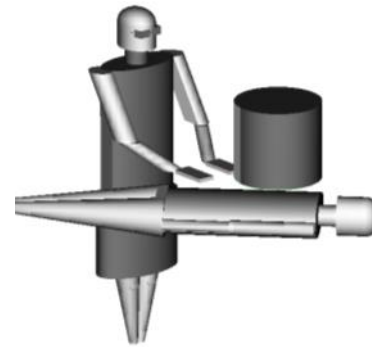
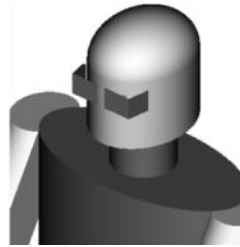
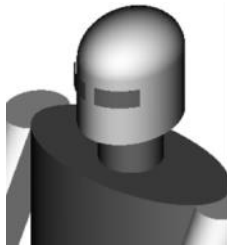
No ceiling screen ; Left eye

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

Ceiling screen ; Left eye

- Median dose: 18 µSv
- 95% CI [8; 57]

- 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**

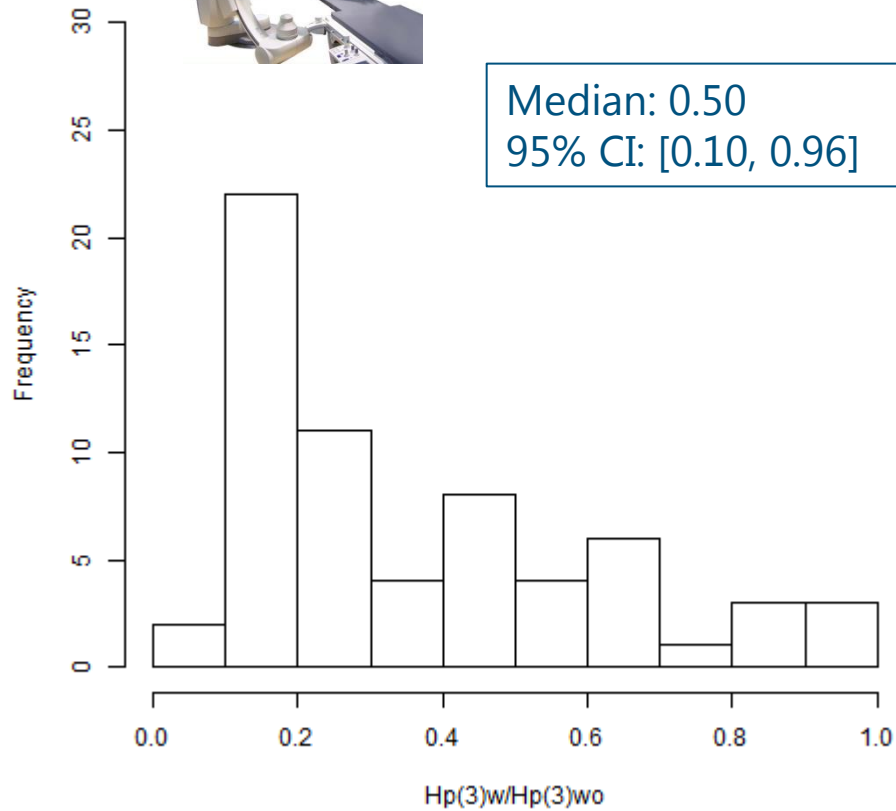
} 20 combinations

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

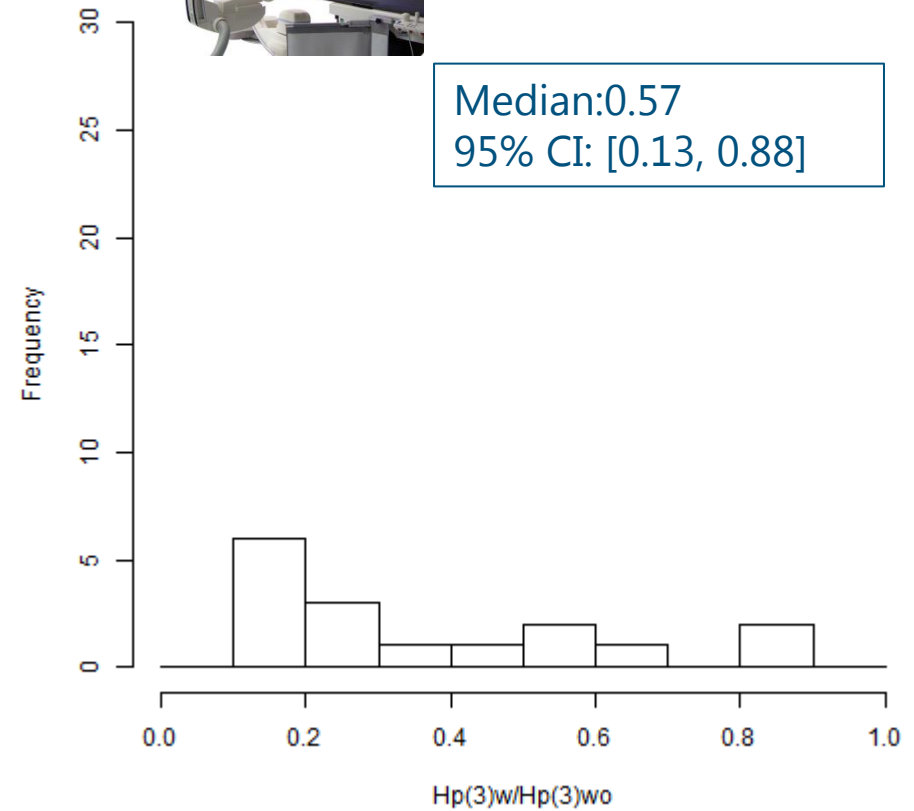
- Effect of lead glasses → Monte Carlo simulations



Monoplane



Biplane



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*)

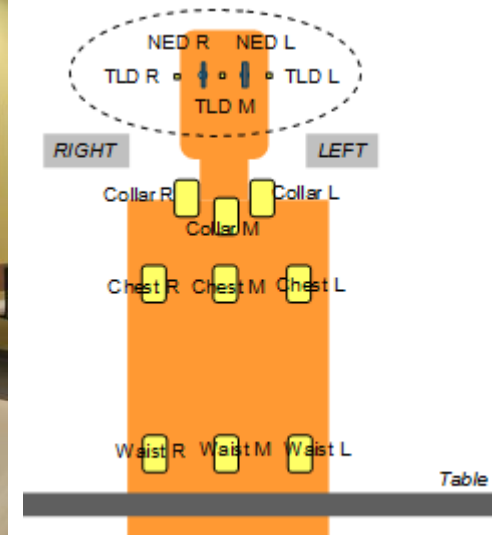
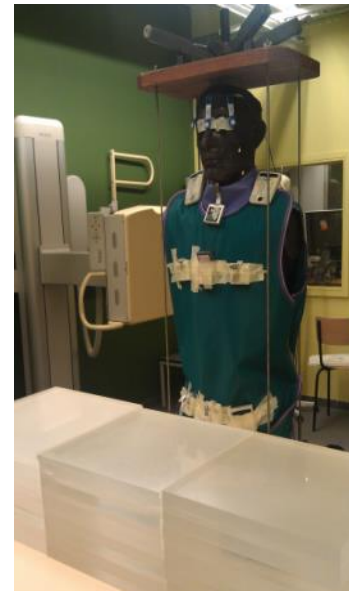
Collected in the occupational questionnaire ←

Approach 2: Conversion from whole body doses

- European ELDO project (funded by DoReMi network)

“Correlation between eye lens dose and whole body dose”

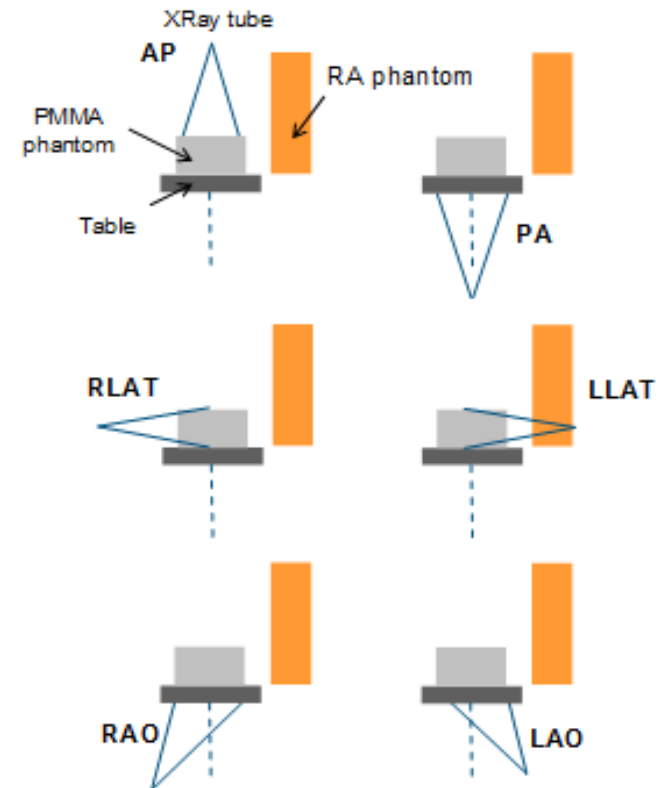
- Measurement of eye lens doses and whole body doses in clinical conditions
 - Operator: Rando-Alderson phantom
 - Patient: PMMA plates
 - Passive and active dosimeters
 - Measurements **above the lead apron**
 - Eye level
 - Collar level
 - Chest level
 - Waist level
 - Left – middle – right side



- 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

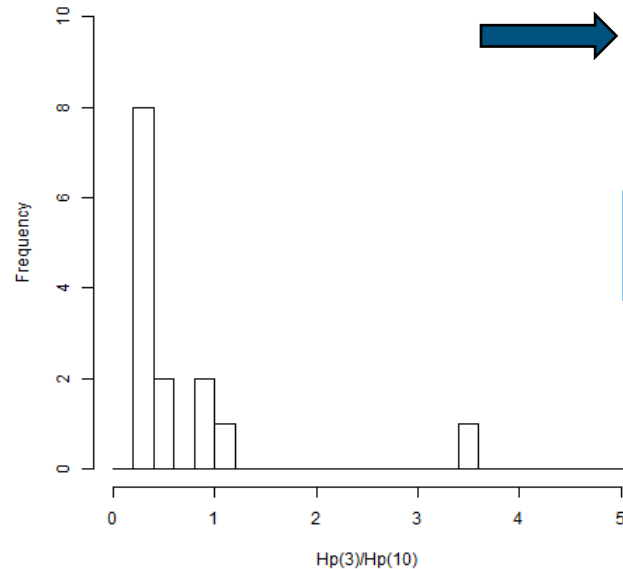
	Distance_Projection
1	0cm_AP
2	0cm_PA
3	0cm_RAO
4	0cm_RLAT
5	40cm_AP
6	40cm_PA
7	40cm_RAO
8	40cm_LAO
9	40cm_RLAT
10	40cm_LLAT
11	40cm_PA_LLAT
12	40cm_RAO30_LAO30
13	40cm_RAO45_LAO45
14	70cm_AP
15	70cm_PA
16	70cm_RAO
17	70cm_LAO
18	70cm_RLAT
19	70cm_LLAT
20	62cm_PA_LLAT

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

RF ablations, ChestL to EyeL



$$D \left[\frac{H_p(3)}{H_p(10)} \right]$$

For each position of the whole body dosimeter

● 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

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

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

Approach 2: Summary

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

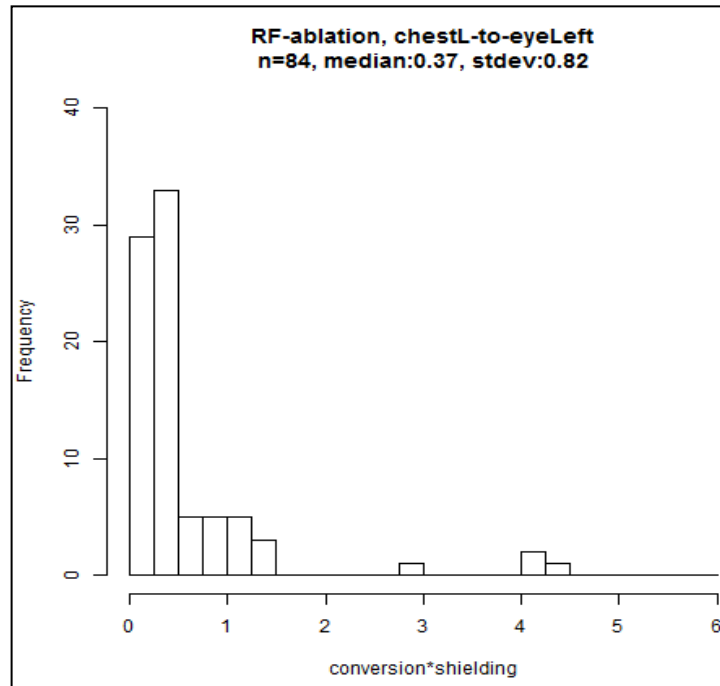
i : year
 j : type of procedure

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

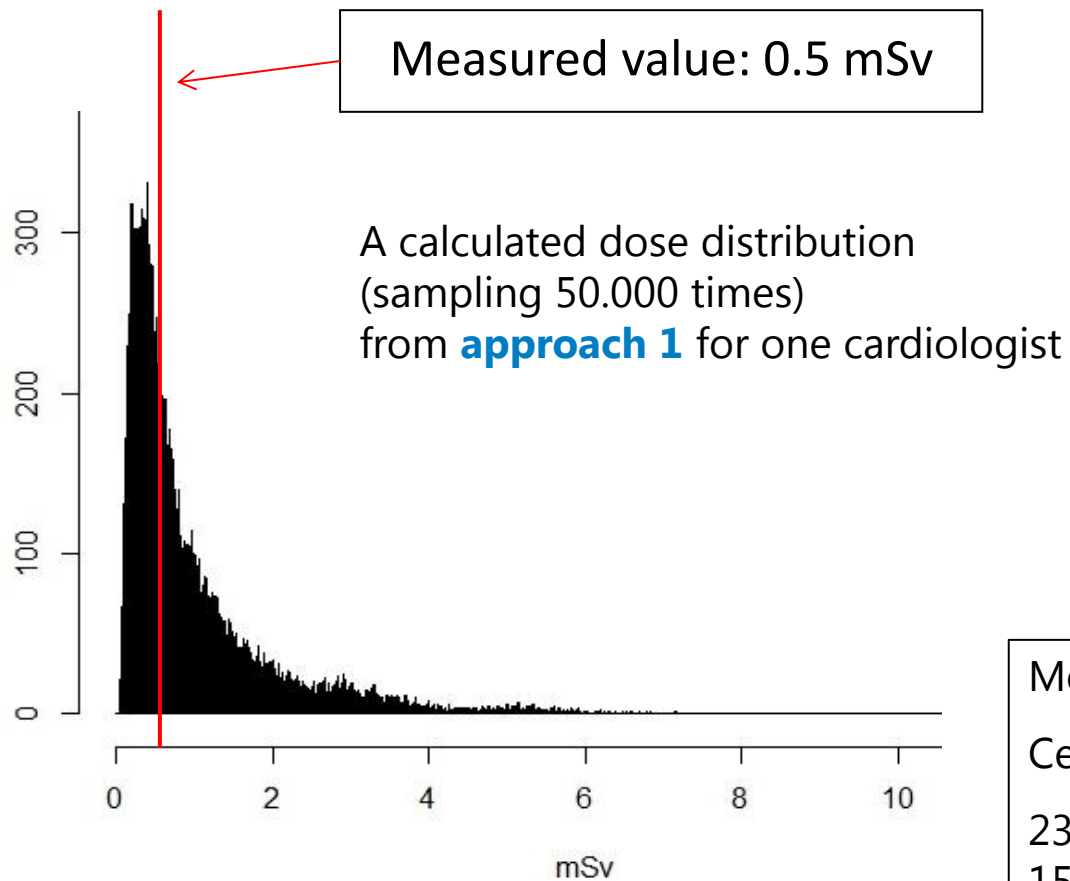


Validation of methodology

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



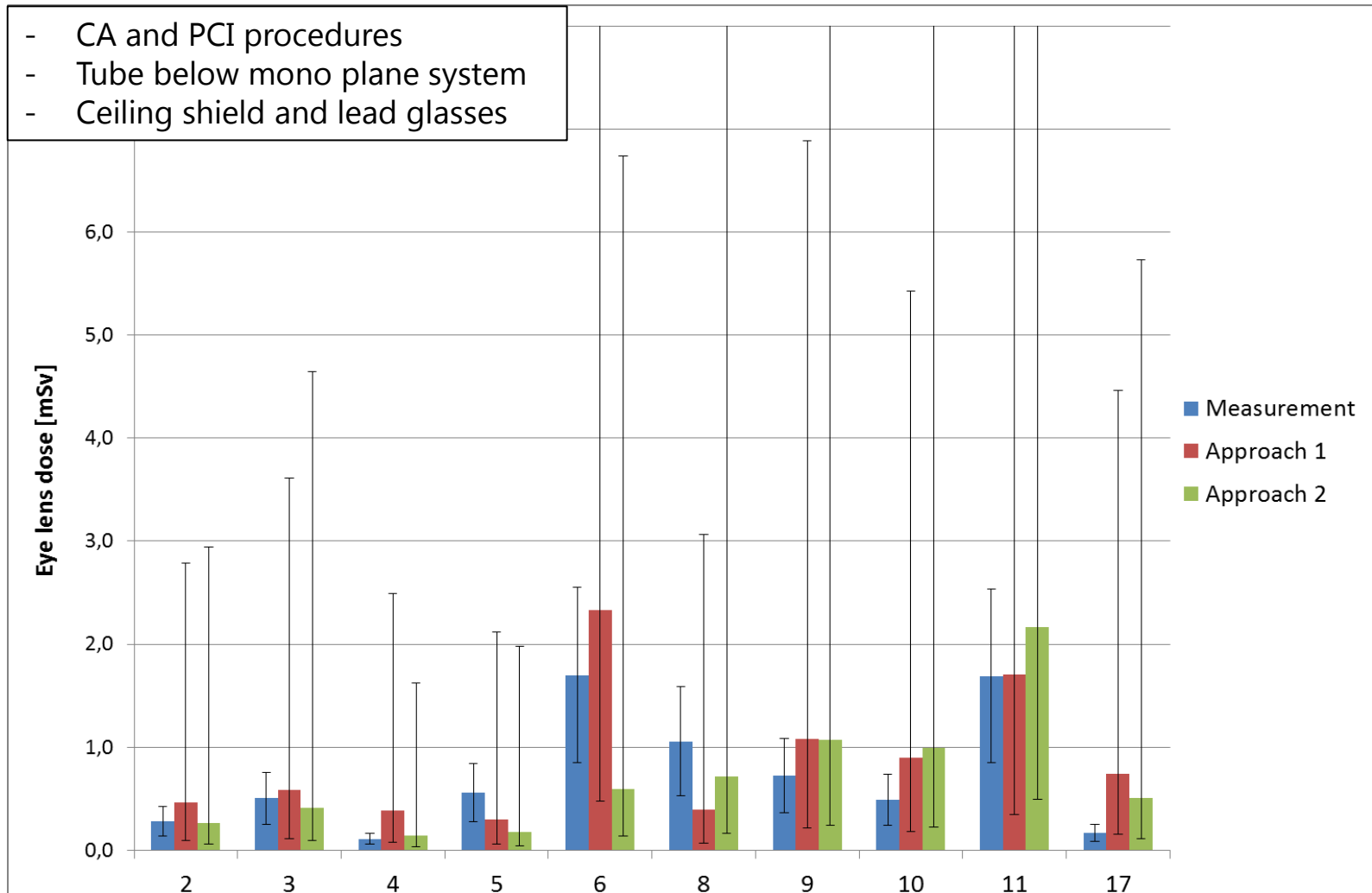
Validation of methodology



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



- The **retrospective** calculation of **cumulative** eye lens dose for **interventional cardiologists**
- 2 complementary approaches

Individual working history +
eye lens dose data from literature

- **Direct** eye lens dose measurements
- **Individual** occupational history
- **Evolution** over the years
- Consider the **number of procedures**



- **Large spread** in available eye lens dose data
 - even for similar working practices
- Confidence in **self reported** info from early years



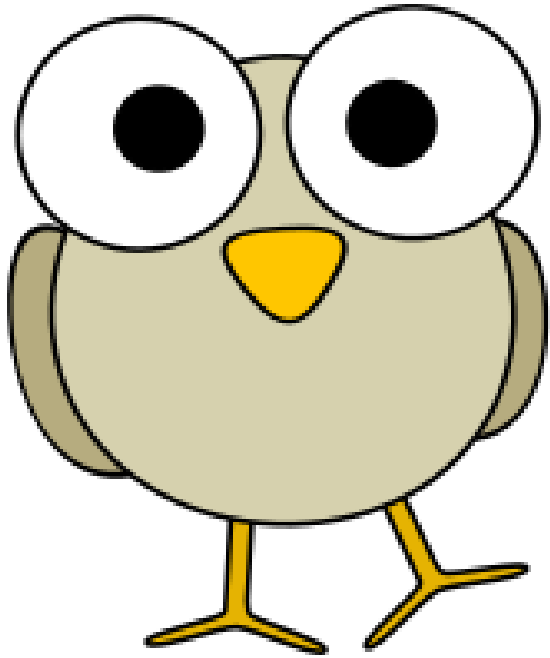
Conversion from whole body
to eye lens dose

- Use of **personal** dose information of recruited cardiologist



- **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