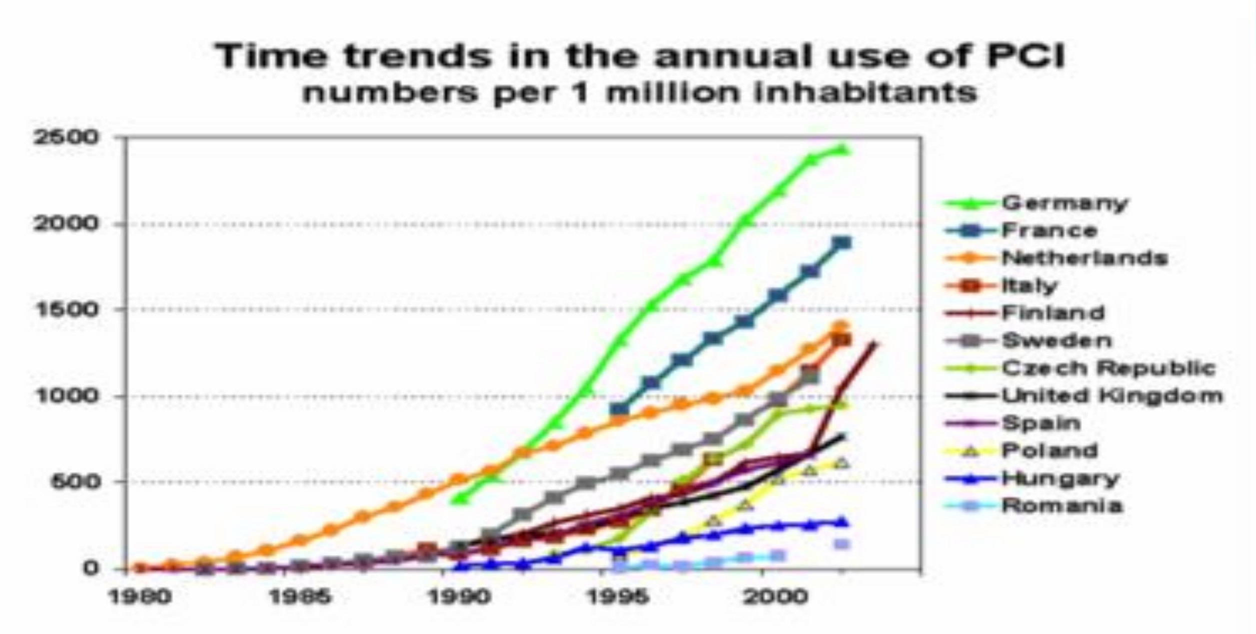
IAEA
International Atomic Energy Agency

5. Case Study 2: Optimization of occupational radiation protection in interventional cardiology

Percutaneaous Cardiac Interventions (PCI) Trends in Europe from 1980



Selected IC procedures

- Cardiac angiographies (CA) and angioplasties (PTCA)

- Pacemaker and Cardiac Defibrillator implantations (PM/ICD)

- Radiofrequency ablations (RF)

Available fluoroscopic systems

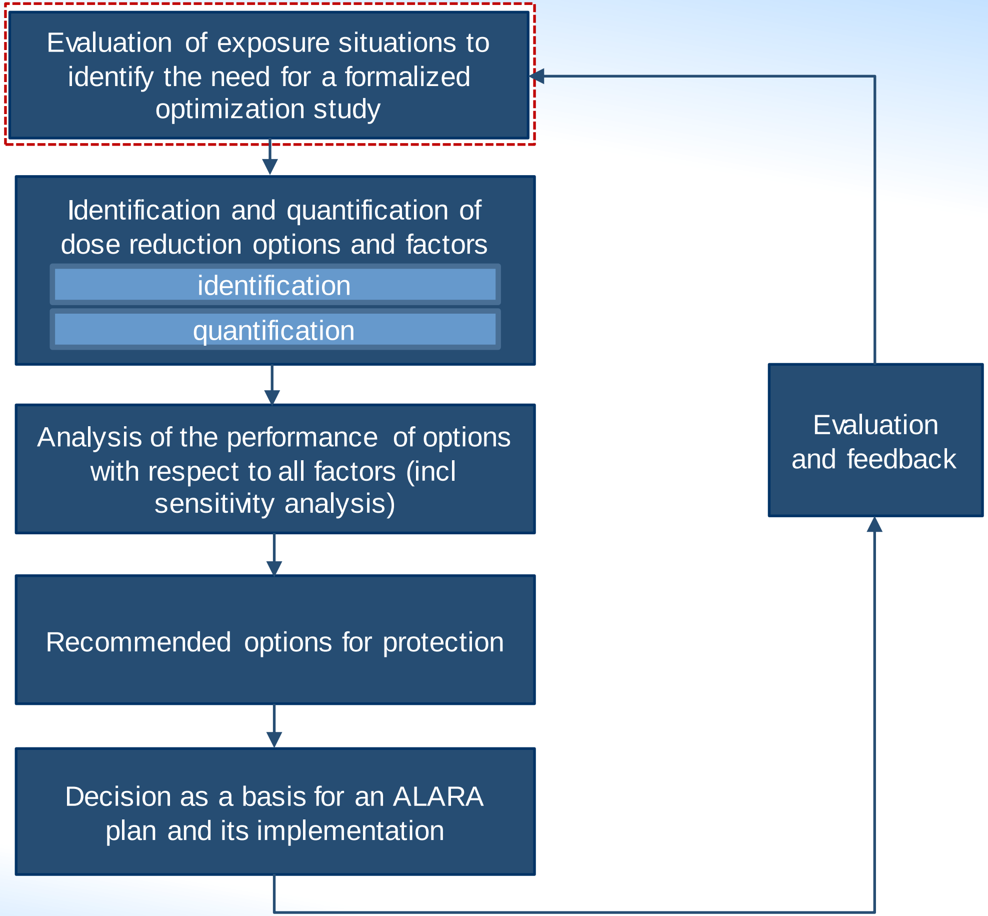
Angiography C-arm system

Biplane C-arm system

Mobile C-arm system

Remotely controlled-
Tube over the table

Tableside-controlled
Tube under the table


Evaluation of exposure situations to identify the need for a formalized optimization study
Identification and quantification of dose reduction options and factors
identification
quantification
Analysis of the performance of options with respect to all factors (incl sensitivity analysis)
Recommended options for protection
Decision as a basis for an ALARA plan and its implementation
Evaluation and feedback

Stakes: Is the exposure to the cardiologist much higher than to non-interventionalists?

The radiation exposure of the cardiologist is of significance principally for following three reasons:

location - has to work inside and near the X ray tube and cannot be too far away from the patient;

time - the radiation 'ON' time in a well utilized catheterization laboratory is typically a few hours per day (say 60-200 minutes) in contrast to a radiography room where it is generally two-four minutes for a workload of 100-200 radiographs per day;

shielding - attenuation by lead apron can be to the order of 90-97% depending upon the lead content of the apron whereas higher attenuation is possible with structural shielding for those who work at the console outside the X ray room.

Stakes: Is there a risk of cataract when working in a catheterization laboratory?

IAEA

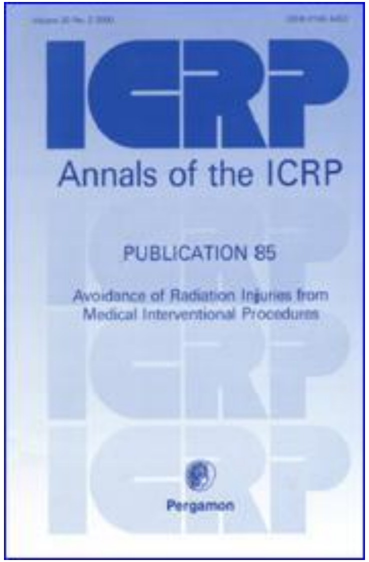
Results from recent studies conducted by the IAEA (RELID) reveal the prevalence of radiation associated posterior lens opacities range from 38 - 52% for interventional cardiologists, 21 - 45% for nurses

Relative risks of lens opacity is 5.7 for interventional cardiologists and 5.0 for nurses.

Estimated cumulative ocular doses range from 0.01 to 43 Gy with mean and median values of 3.4 and 1.0 Gy, respectively.

A strong dose-response relationship is found between occupational exposure and the prevalence of radiation-associated posterior lens change

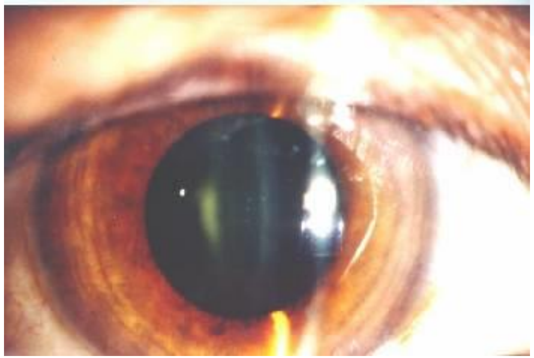
Stakes: ICRP report 85 (2001): Avoidance of Radiation Injuries from Interventional Procedures



The British Journal of Radiology, 71 (1998), 728–733 © 1998 The British Institute of Radiology

Lens injuries induced by occupational exposure in non-optimized interventional radiology laboratories

[1]E VAÑÓ, PhD, [1]L GONZÁLEZ, PhD, [2]F BENEYTEZ, MD and [3]F MORENO, MD



Cataract in eye of interventionalist after repeated use of old X ray systems and improper working conditions related to high levels of scattered radiation.

Stakes: Is there a risk of cataract when working in a catheterization laboratory?

The RELID findings were inconsistent with the 2000 and 2007 International Commission on Radiological Protection (ICRP) threshold of 5 Gy for “detectable opacities” from protracted exposures.

However, these data agree with the new threshold of 0.5 Gy for detectable lens opacities that was recently proposed in the ICRP statement

Stakes: Recent evolution of ICRP position
ICRP statement (April 2011) and IAEA Safety Standard

"The Commission has now reviewed recent epidemiological evidence suggesting that there are some tissue reaction effects, particularly those with very late manifestation, where threshold doses are or might be lower than previously considered. For the lens of the eye, the threshold in absorbed dose is now considered to be **0.5 Gy**."

"For occupational exposure in planned exposure situations the Commission now recommends an equivalent dose limit for the lens of the eye of 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv".

Stakes: ICRP now says: optimisation is not any more restricted to whole body dose (i.e to stochastic effects) but should be expanded to deterministic effects management

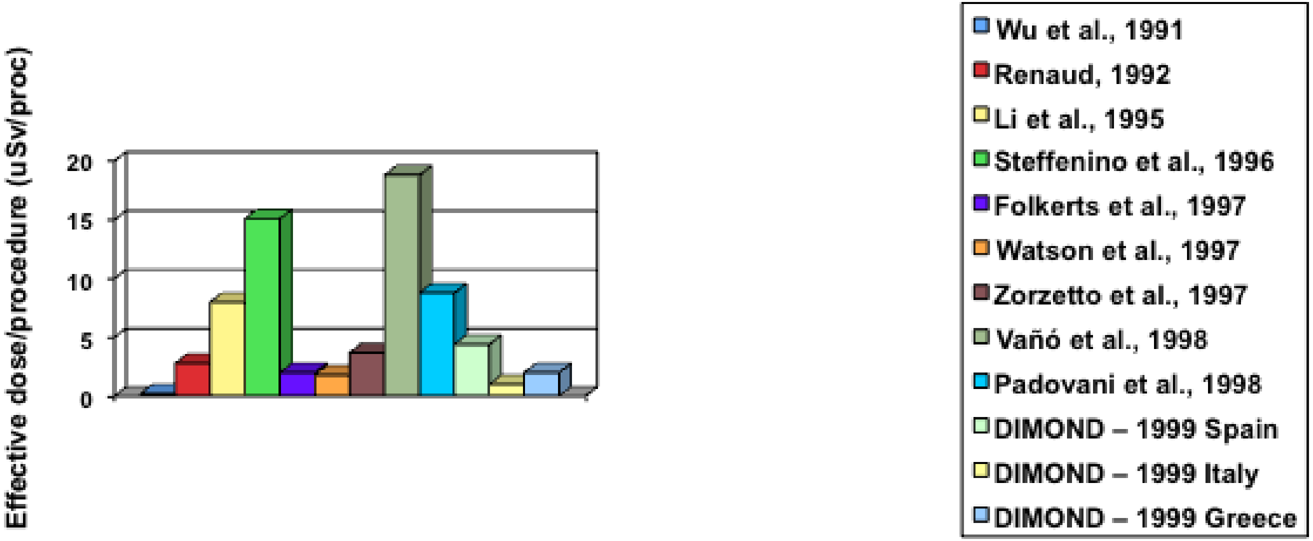
"The Commission continues to recommend that optimisation of protection be applied in all exposure situations and for all categories of exposure. With the recent evidence, the Commission further emphasises that protection should be optimised not only for whole body exposures, but also for exposures to specific tissues, particularly the lens of the eye, and to the heart and the cerebrovascular system."

This means that ICRP takes care of new evidences as an indicator of a less certain knowledge, and therefore consider the thresholds and corresponding limits not enough for guarantying a "safe" situation" to exposed people

The exposures should then be reduced reasonably even under the limit for those organs

Stakes: what are the staff's effective doses?

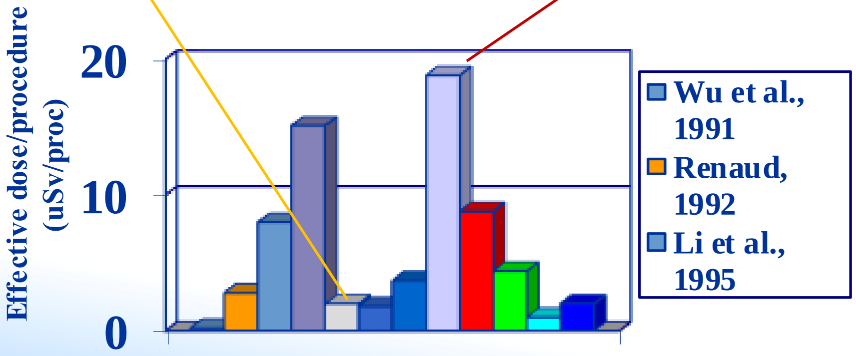
- Literature shows that there is a large variability of doses to staff (data in micro.Sievert per procedure)



Stakes : can the effective dose limit be reached?

- Operator 2: 1000 procedures/year
  - 2 µSv/proc
  - E= 0.002*1000=2 mSv/year = 1/10 annual limit

- Operator 1: 1000 procedures/year
  - 20 µSv/proc
  - E= 0.02*1000 = 20 mSv/year = annual effective dose limit



Stakes : bad radiological protection practices,

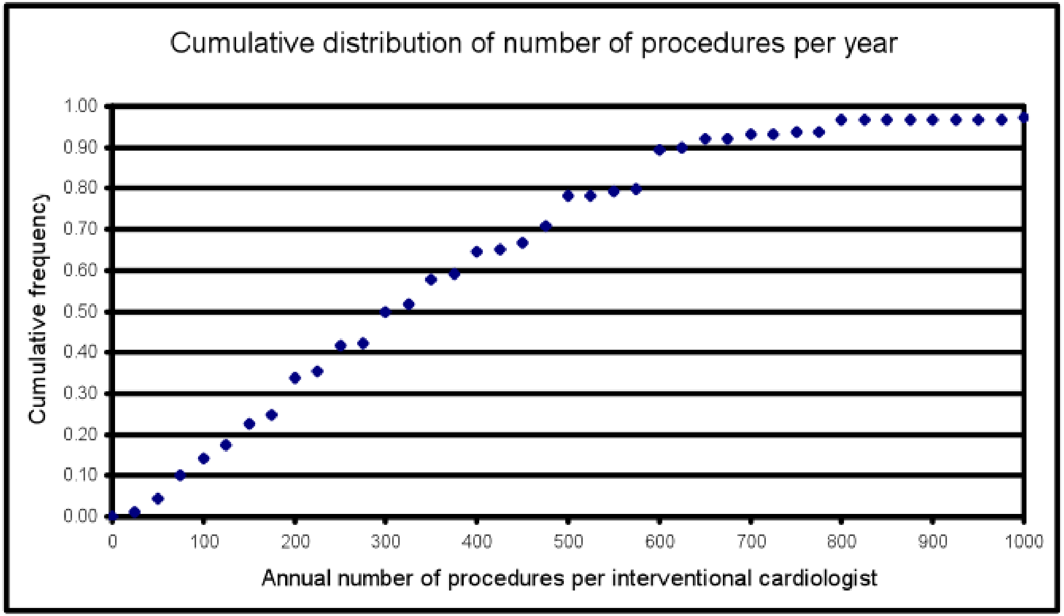
> 1/4	< 40 %	83%	Lv.1
do not wear regularly dosimeters !	would always be using all protective tools	said they had a RP training but only one half has a certification in RP	RP habits in countries Health care level 1 (WHO definition) are better than in other countries

2009 ISEMIR WGIC survey results, answers from 201 cardiologists from 32 countries worldwide

- The results of the survey are surely not representative of the worldwide situation in terms of actual behaviour of the profession, but……
- … the answers are certainly over optimistic as those who answered were, quite evidently, more sensitive to radiological protection than the others

Stakes : the number of procedures per cardiologist , the 2009 ISEMIR WGIC survey results

In 2008, the average annual number of procedures performed by cardiologist is 400 and vary from 50 to 1500



Then what to do?

All over the world there is an increasing trend of procedures performed

Actual doses are often very badly followed and known

Both eye lens, hands and effective dose limits may be exceeded when good radiological protection practices are not implemented

Even in some cases deterministic effects have been observed

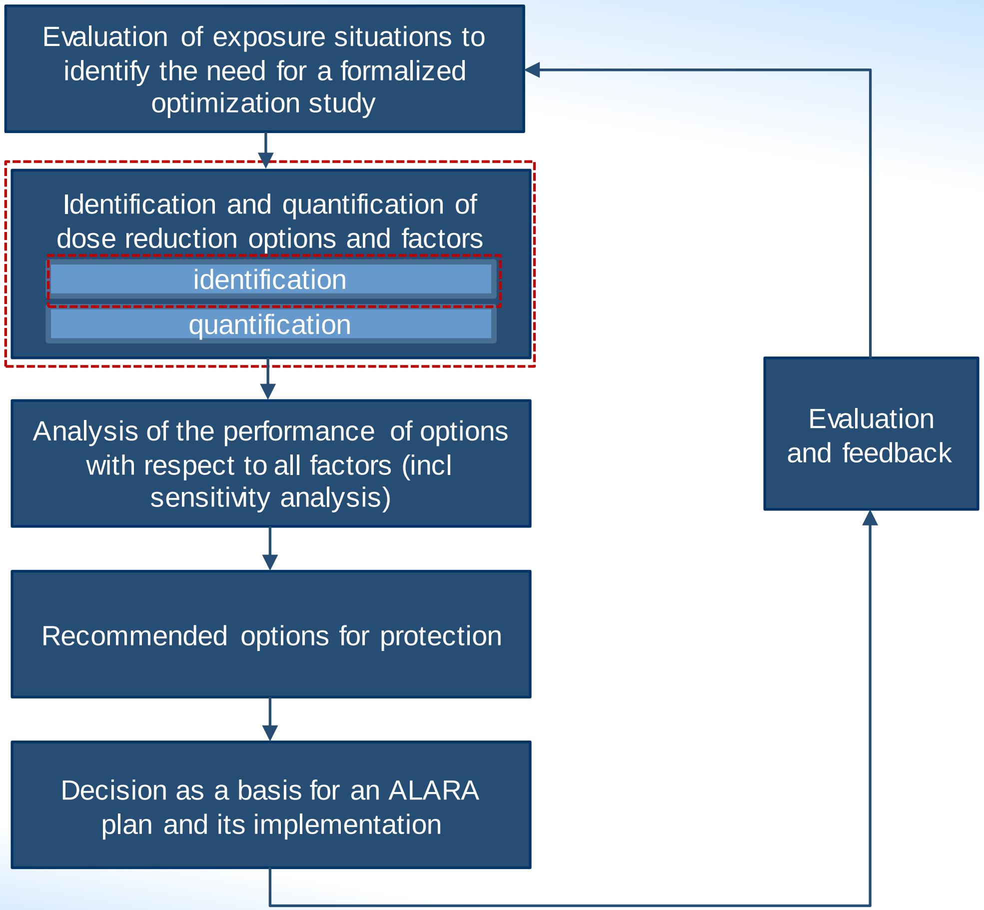
And in many cases precursors such as lens opacities are observed

It is mandatory to **implement** good **optimisation of radiological protection** both for avoiding deterministic effects and reducing as low as reasonably the probability of stochastic effects.

As a conclusion of step 1

- The stakes are enough important for justifying several teams around the world performing in depth generic optimisation studies, with support of national or even international resources.

- This will not prevent each RPO to adapt the results of the generic study to his own local context


Evaluation of exposure situations to identify the need for a formalized optimization study
Identification and quantification of dose reduction options and factors
identification
quantification
Analysis of the performance of options with respect to all factors (incl sensitivity analysis)
Recommended options for protection
Decision as a basis for an ALARA plan and its implementation
Evaluation and feedback

IDENTIFYING: What are the possible options?

what do you need to know to propose protection actions?

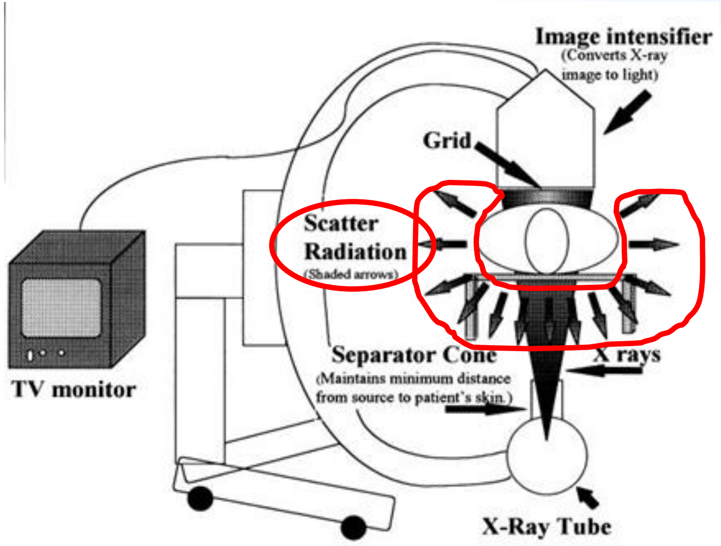
What are the sources and dose rates? (1)

The only origin of the dose being the **X ray machine**, no dose will occur, neither for the patient nor for the worker when the X Ray machine does not work i;e when there is no image under taking

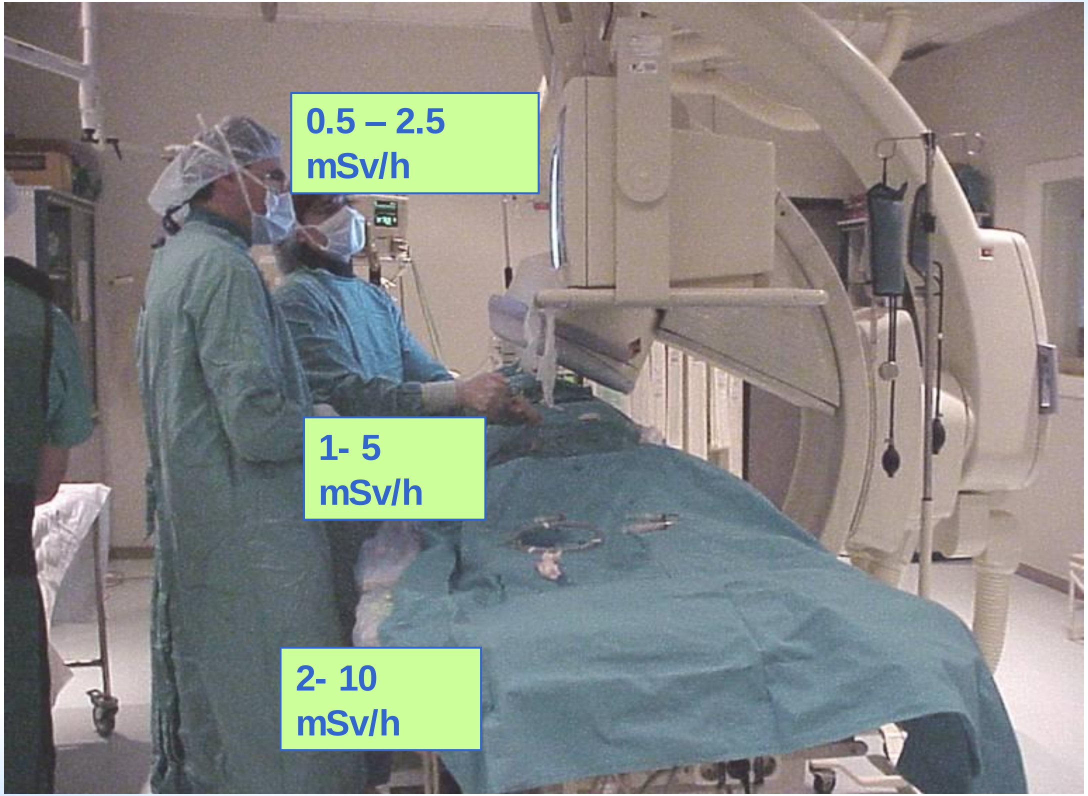
Main dose steam into the beam **(workers' hands** can be there)

Most of the dose to the workers comes from the **scatter radiation from the patient**: patient is the main source for the workers as illustrated in the following graphs.

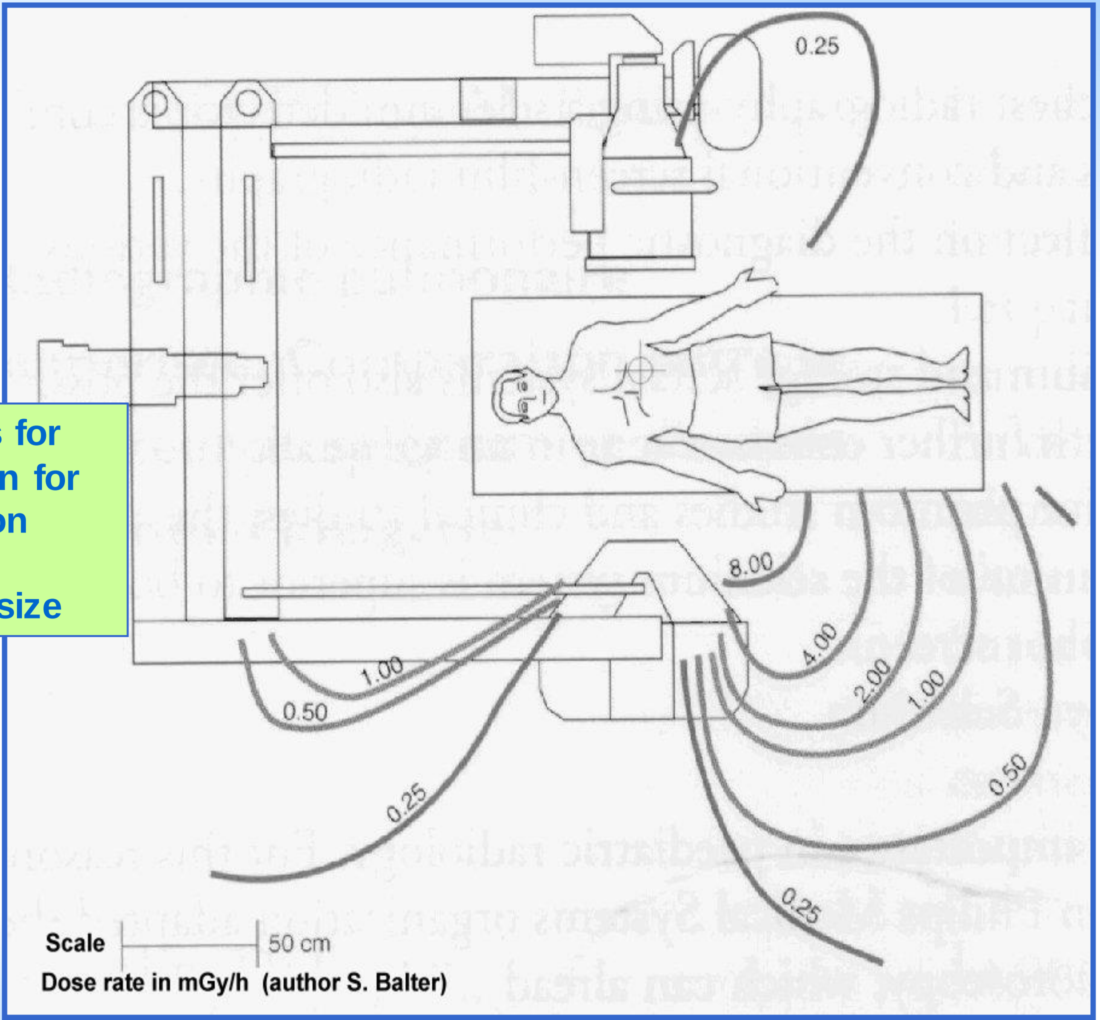
Medical staff involved in interventional procedures is exposed by the radiation scattered by the patient



Typical dose rates in IC procedures



Isodose curves for scatter radiation for typical operation conditions and typical patient size



Typical dose distribution in IC procedures

Vascular surgery procedure % of the scatter dose measured at the C-arm
San Carlos University Hospital Madrid

IDENTIFYING:
What are the possible options?

Taking care of your feedback,…

Making use of brain storming,…

…, what can be envisaged for reducing doses?

- Source reduction
- Time reduction
- Shielding actions
- Working conditions?

Source reduction

Quite simple actions

- To collimate the X ray beam to the area of interest.
- To select the good angle of the C-arm if Bi modal (*)
- To optimise acquisition parameters (kV, mAs, filtration)(*)

Other?

Less simple

- If the tube is above the table, one can envisage to change the device in order to benefit from tube below the table for the worker to be as far as possible from too “strong” beam without modifying the dose to the patient

** The angle as well as the collimation only when medical procedure allows it*

Exposure Time Reduction?

Minimize number of pictures (radiography)

Minimize fluoro and cine times

Use pulsed fluoroscopy– minimizes time X ray tube is producing X rays

Whenever possible, step out of room : a good idea but not technically possible in cardiology; (possible for radiologists) = NOT AN OPTION HERE

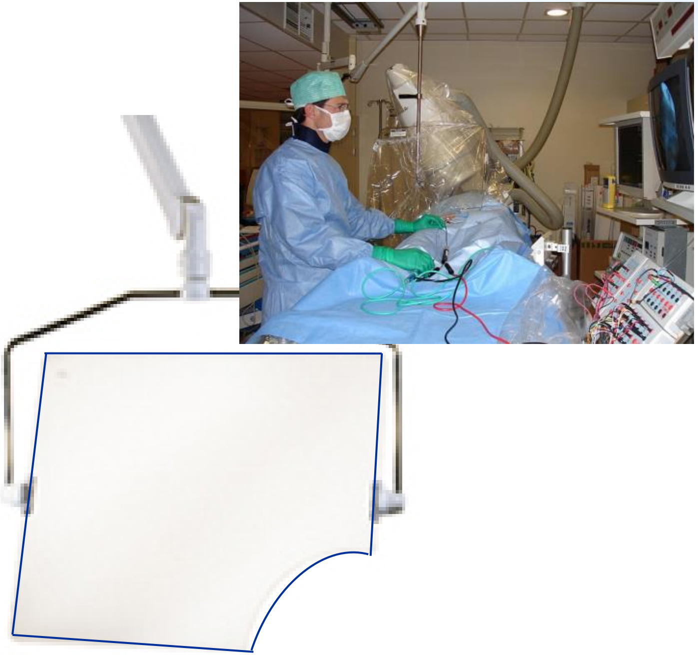
Step behind barrier (or another person) during fluoro or cine

Other?

What kind of collective shielding is possible?

Ceiling suspended shield

Transparent + drapes



Transparent in arc shape

What kind of collective shielding is possible?

Table shield

What kind of collective shielding is possible?

- *Mobile screens may be available for protecting workers other than IC when they have to stay in the room*

What kind of Personal Protective equipment is possible?

Glasses

Thyroid collar

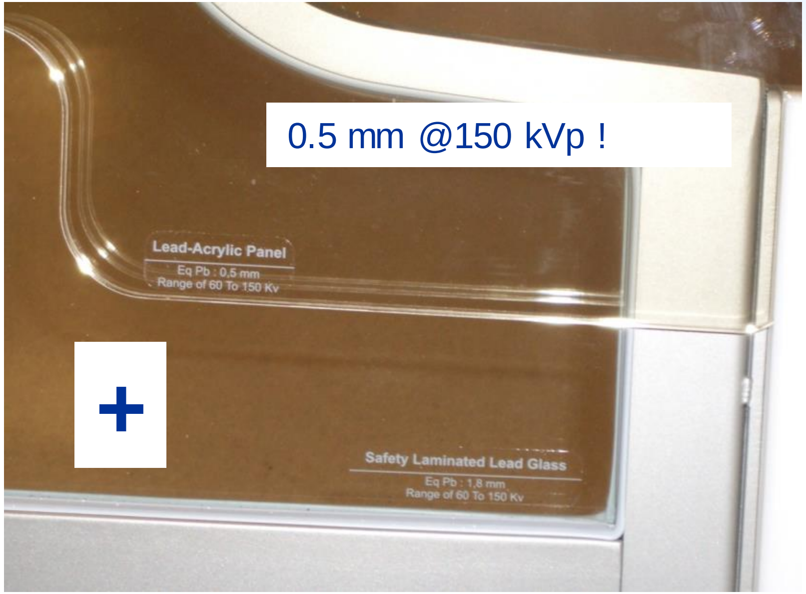
Gloves

Lead protective apron

What kind of Personal Protective equipment?

The Ultimate! Whole body cabin shield.

IAEA



0.5 mm @150 kVp !

+

1.8 mm @150 kVp !

Actions on working conditions and organisation

As is it well known that bad working conditions and organisation have a direct impact on worker's exposures, the question is :

Are they possible actions in that domain?

- Is there enough or too much light?
- Is there enough room?
- Are the workers well trained in radiological protection ?
- Are the procedures for cleaning the protections adapted?
- ……

Actions on working conditions and organisation

This should have an important impact on actual occupational doses.

However it is mainly related to the specific context of the installation

This is mainly the responsibility of the department and will not be addressed within a generic optimisation study

However this remains an important part that should be addressed in an optimisation study at the local level, even if it is not under the responsibility of the RPO.

Conclusion 1 step 2 .1
Synthesis table : possible actions identified

IAEA

Actions on time

- To optimise acquisition parameters
- Number of radiography pictures
- Minimize fluoroscopy and cine times
- pulsed fluoroscopy

Shielding

- Collective
  - Ceiling suspended
  - Table shield
  - Mobile screen
- Individual
  - Glasses
  - Colar
  - Apron
  - Gloves
  - Whole body cabin

Actions on source

- Collimation
- Angle
- Tube below the table

Actions on working conditions

- enough room?
- enough or too much light?
- well trained workers
- Good cleaning procedures
- …

IDENTIFYING

What about criteria for decision making ?

- Of course efficiency in terms of dose reduction,
  - but what doses?
- And then the costs?
  - What are the costs?
- What do you suggest as other criteria for the decision making ?

Conclusion 2 step 2 .1

Synthesis table : possible factors identified?

Efficiency in dose reduction

- Reduction in dose to lens
- Reduction in dose to hands
- Reduction in dose to legs
- Reduction in effective dose

Types of costs

- Amortisation of Investment and installation Costs?
- Operating Costs (consumables, cleaning, waste handling…)?

Can we take care only of costs and dose reduction?

NO……… WHY?

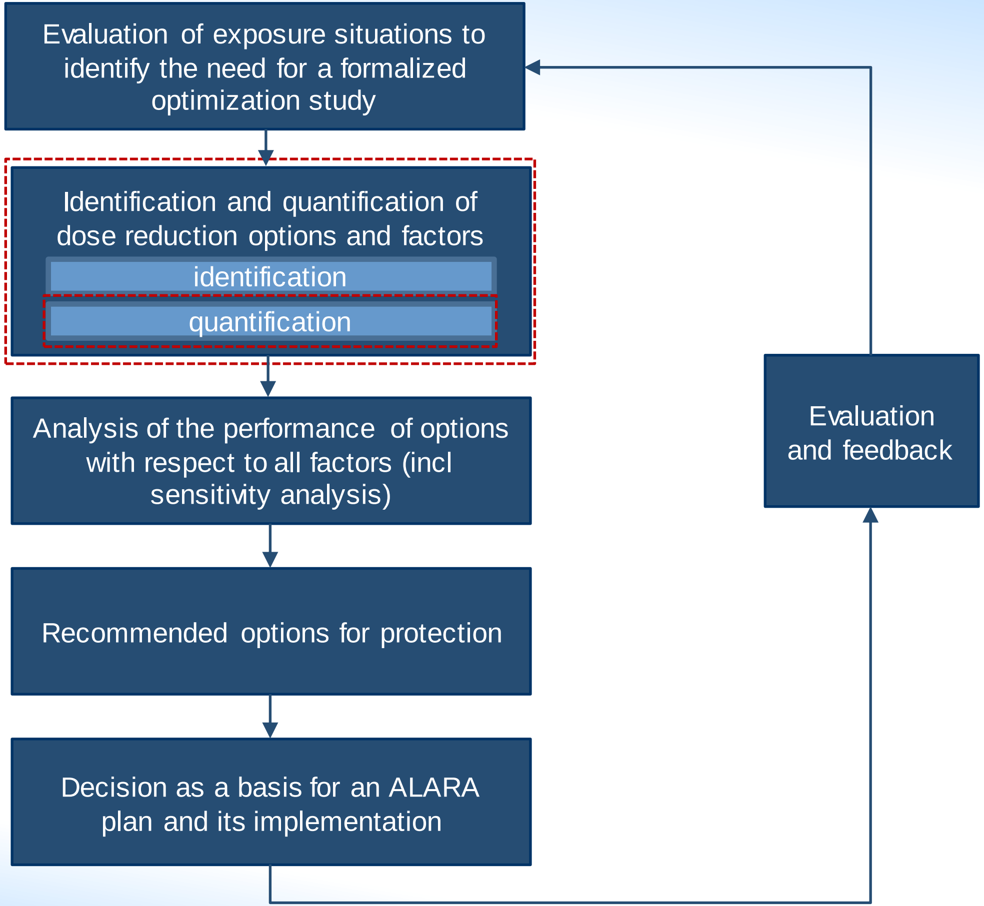
Conclusion 2 step 2 .1

Synthesis table : possible factors identified?

Because a lot of other factors should be taken into account

First of all of course the constraints corresponding to the medical decisions and the efficiency of the medical procedure

- Impact on medical efficiency?
- Impact on dose to patient?
- Easiness for medical reaction in case of patient trouble?
- Impact on training?
- Weight painful?
- Impact on kidney pathologies for the patient?
- Impact on perceived equity and union position?
- Any Others?


Evaluation of exposure situations to identify the need for a formalized optimization study
Identification and quantification of dose reduction options and factors
identification
quantification
Analysis of the performance of options with respect to all factors (incl sensitivity analysis)
Recommended options for protection
Decision as a basis for an ALARA plan and its implementation
Evaluation and feedback

Quantification of factors?

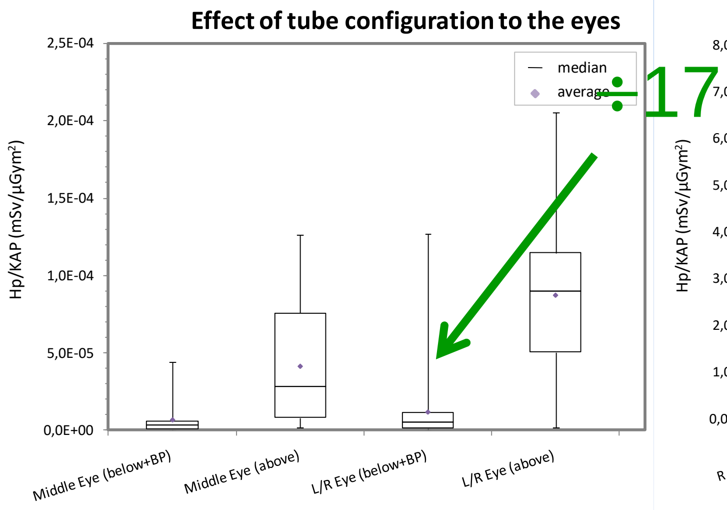
IAEA

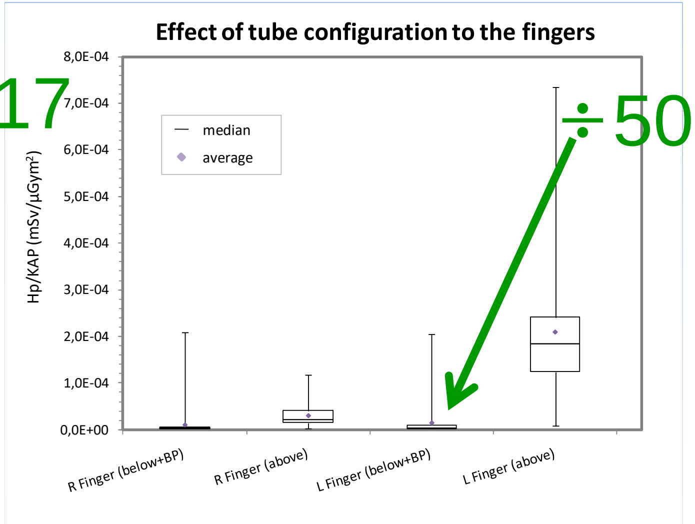
We will check successively for each option
The efficiency, the costs, and the impact on other criteria
Following the same order

- Source reduction
- Time reduction
- Shielding actions

Tube below the table (1)

Below the operating table there is a significant reduction at the eye (2-17 times) and hand doses (2-50 times). However, there is an increase at the leg doses





Tube below the table (2)

When installing a new room, always select that **type of table**

If the device already installed has its tube above the table (normally not the case in cardiology), envisage to change it as soon as possible.

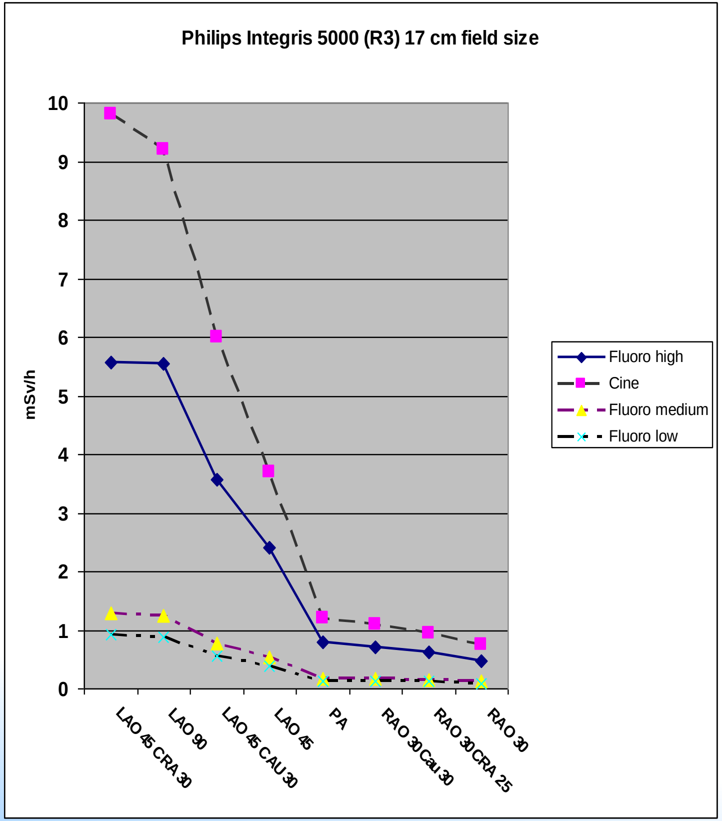
May be the old device may be used in (or returned to) a classical radiology room?

The cost of replacement is not trivial, the investment should be of the order of 700000 Euros, even more if the selected device is Biplan (up to 1200000 Euros).

So, in normal operation the replacement of the device cannot be considered as technically feasible. It will not be considered as an available protection option.

Influence of operation modes

from low fluoroscopy to cine, scatter dose rate could increase in a factor of 10 (from 2 to 20 mSv/h for normal size)



Scatter dose values at the left shoulder of the cardiologist without extra shielding
(experimental results from E. Vano)

From the image quality point of view, image from cine are less clear than fluoroscopy ones (see oramed results in annex 2)

Modifying these parameters costs nothing but modifying habits and culture through training

Good angle of C arm

For scatter dose the orientation of the C-arm is dominant in comparison with the entrance patient dose rate.

Different C-arm angles can modify the scatter dose rate by a factor of 5

Of course, this is also a no cost option

Ceiling suspended shield

- Typically equivalent to 0,5mm lead
- Not available in all the rooms
- Not used by all the interventionalists
- Not always used in the correct position
- Not always used during all the procedure

Ceiling suspended shield: Efficiency

IAEA

When the ceiling shield is properly used there is a significant reduction of the eye dose (2 times; remaining dose 50%).

Dose PDS median without / with ceiling suspended shield		
	Eye L/R	Forehead
CA/PTCA	1,6	2,3

In reality the remaining dose should be 5 to 10%; the ORAMED measures give much less efficient results as the shield is often not used properly.

Ceiling suspended shield: costs and other criteria

The cost of such a ceiling shielding is around 4000 € plus installation ; i.e 6000 €

Cannot be used for all procedures

No impact on patient dose

No pain for the workers

Just to put it in the right positions at the right times

Table shield (1): efficiency

Efficiency

The table shield can reduce the dose to the legs up to a factor 3.5(remaining dose nearly 30%)

Dose PDS median without / with table shield		
	Tibia L	Tibia R
CA/PTCA	3,5	1,3

As in the case of ceiling shield, in reality the remaining dose should be 5 to 10%; the ORAMED measures give much less efficient results as the shield is often not used properly

Costs and other criteria

The cost of such a ceiling shielding is around 2000 € plus installation ; i.e 3000 €

No impact on patient dose

No pain for the workers

Just to put it in the right positions at the right times

Mobile screen

In a global optimisation study this should also be taken into account, according to the actual stakes for the other workers than the cardiologists

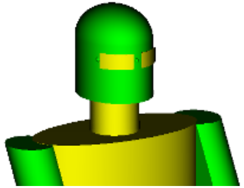
The cost of such a shielding is around 2 to 3000 €

The mobile shield is not so easy to move, in particular when the floor is not very flat, so this has to be taken into account as well as the cost efficiency of that option.

For simplification reasons we will not take it into account any more for the end of the case study

Glasses: Efficiency

They may be considered as substitute to the ceiling suspended shield, the remaining dose being here 14%



ORAMED Simulations: 90 kVp, 3 mmAl		
	Left eye Attenuation factor	
	PA	CRA20
No glasses	1	1
Small lens (0,5 mmPb)	3,3	3,6
Large lens (0,5 mmPb)	6,7	7,1
Small lens thick(1,0 mmPb)	3,8	4,0
Large lens thick (1,0 mmPb)	7,1	7,7

- *Lens 0,5 mmPb thick are enough protective with regards to the attenuation and weight .*
- *Large lens, with lateral protection are much more efficient*

Glasses

Costs and other criteria

The shielded glasses purchase cost is around 200 €

After quite a lot of uses during 4 years they will increase the wastes

Wearing glasses can be considered as an obstruction by the cardiologists , or providing them with headache, and these may be reducing their skilfulness

They have no impact on the patient dose

Efficiency

But sometimes they should be complementary in the real life, as the ceiling is not always usable during the procedure.

Other sources show that the attenuation can be nearly 99%: the remaining dose being only 1%

0,25 mm Pb is often enough and less heavy.

Source : Eliseo Vano

Collar

Efficiency

- May they be partly considered as substitute to the ceiling suspended shield
- More than 50 times dose reduction at thyroid; the remaining dose being then 2%

Costs and other criteria

- The purchase cost is 100€
- After quite a lot of uses during 4 years they will be put in the wastes
- Disadvantages of the thyroid collar are discomfort and important hygienic problems
- Wearing collar can be considered as an obstruction by the cardiologists
- They have no impact on the patient dose

Lead aprons

Efficiency

They are neither substitutes to ceiling nor to table shields

Lead apron typically attenuates >90%
Vest-Skirt Combination distributing 70% of the total weight onto the hips leaving only 30% of the total weight on the shoulders.

Option with light material reducing the weight by over 23% while still providing 0.5 mm Pb protection at 120 kVp

Costs and other criteria

The purchase cost of a full lead apron is typically 700 €

It will last 4 years if well cleaned, and then become waste

Wearing the apron may be considered as painfull

It has no impact on the patient dose

Protective Surgical Gloves : efficiency

With an equivalent 0,03mmPb, the dose reduction to the hands is only on the order of 60% to 50%, no more, so the efficiency is quite seldom (often less than a factor 2)

However a gloved hand moving into the primary beam may be counterproductive as it causes extra scattered radiation coming towards the exposed worker (7%). It may also increase the acquisition parameters, and therefore patient and **workers** doses, by more than 20%

Wearing gloves can also lead to bad practice when providing the cardiologist with a false feeling of safety which leads to take more time, increasing dose to the patient and to other workers as well

Protective Surgical Gloves : cost and other criteria

The cost of purchase for a pair of gloves is 30 €

However, they are available for a very few uses (between 1 to 5)

They immediately after that go to waste

A great disadvantage: they may seriously hamper accurate locomotion of hands and fingers.

Whole body cabin: efficiency

- The whole body cabin can be considered as an alternate (equivalent or better) to most of the other individual protections for the Cardiologist when used (see pub EHJ 2006
- Of course if he has to perform activities out of the cabin, all other shielding remain useful
- That shielding will only protect the cardiologist, the collective shielding and personal ones remain useful for the other workers.

- Purchase costs: 30000 €
- Specific gloves 40 € usable 15 times
- No impact on patient dose
- Quite heavy to handle

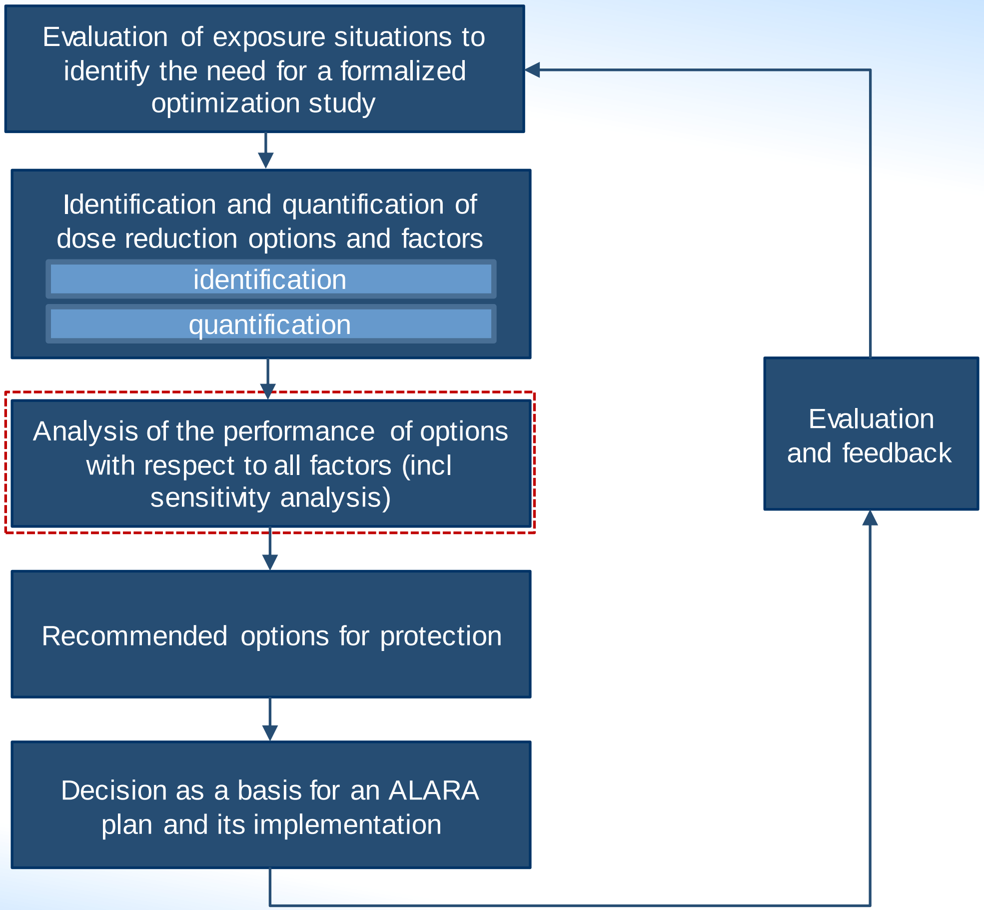
Whole body cabin: costs and other

Purchase costs: 30000 €

Specific gloves 40 € usable 15 times

No impact on patient dose

Quite heavy to handle


Evaluation of exposure situations to identify the need for a formalized optimization study
Identification and quantification of dose reduction options and factors
identification
quantification
Analysis of the performance of options with respect to all factors (incl sensitivity analysis)
Recommended options for protection
Decision as a basis for an ALARA plan and its implementation
Evaluation and feedback

Analysis

We will first take care of all actions reducing doses at no cost or even reducing cost

In a second time we analyse the costly options and combination of options and check which are reasonable?

Synthesis of criteria for all Options with NO Cost (1)

Action	Dose reduction	Impact on patient dose	complementarity
1. Optimising machine parameters			
Optimum KV, MaS, collimation	Reducing all doses in same proportion	Reducing all doses in same proportion	C to all
Low fluoroscopy	> 10 times all doses	> 10 times all doses	C to all
Reducing number of images in pulse mode	> 2 times all doses	> 2 times all doses	C to all
2. Reducing number of radiography images	Reducing all doses in a same proportion	Reducing all doses in a same proportion	C to all
3. Angle if BI	Up to 5 times	NO	Not C to Table and Ceiling Shields

Synthesis of criteria for all Options with NO Cost (2)

It is also important to mention that in some countries, the collimator as well as the pulsed fluoroscopy are optional, they should then be considered as options taking care of there costs.

They are then not any more in the NO COST package

Options with NO Cost

Most actions reducing doses with no cost are complementary

Most of them reduce both doses to the patient and to all the workers

None of them has a bad mark with regards to another criterion

Therefore the "reference" for optimization should include them as a mandatory basis, at least for all non Bi table

The main problem is then to spread the good radiological protection culture among all concerned stakeholders … and this has a cost !

Dose reduction synthesis Table

(options with costs) complementarities and substitutability

	Dose to the lens	Dose to the thyroid	Dose to the hands	Dose to the legs	Effective dose	C or S
1 ceiling shield	5 to 20 times	5 to 20 times	No effect	No effect	No data	C all but 3, 7
2 table shield	No effect	No effect	No effect	5 to 20 times	Very few	C all but 7
3 glasses	7 to 100 times	No effect	No effect	No effect	No effect	C all but 1,7
4 collar	No effect	50 times	No effect	No effect	No effect	C all but 7
5 apron	No effect	No effect	No effect	few	> 10 times	C all but 7
6 gloves	No effect	No effect	< 2 times	No effect	No effect	C all
7 cabin*	> 10 times	>10 times	No effect	>10 times	>10 times	S all but 6

* Do not allow to protect other workers than the Interventional Cardiologist

Purchase Costs

	purchase cost (€)	Number of uses or duration
Pair of gloves	30	One to five times
Thyroid shielded collar	100	4 years
Shielded glasses	200	4 years
Shielded apron (total covering)	700	4 years
Table shield	3000	10 Years
Ceiling shield	6000	10 Years
Whole body shielded cabin purchase Specific gloves	 30000 40	 10 Years 15 times

Of course you should have to check with your own country's data.

Annual costs calculation

Hypothesis: 1000 procedures per year; 10 individual protections needed
yearly operation cost = procedure cost x 1000
Only one individual per procedure wear gloves
amortisation= investment/ duration

	Type of Action	Operating . cost per procedure (€)	Investment cost (€)	yearly operating Costs (€)	Amortisation per year (€)	total cost per year (€)
1	Ceiling shield		6000		600	600
2	Table shield		3000		300	300
3	Shielded glasses		2000		500	500
4	Shielded apron (total covering)		7000		1750	1750
5	Thyroid shielded collar		1000		250	250
6	gloves	30		30000		30000
7	Whole body shielded cabin	3	30000	2667	3000	5667

The highest annual cost is by far the use of gloves (even without including the cost of wastes)

Annual costs ranking by increasing cost of combination of options

	Type of Action	total cost per year (€)
5	Thyroid shielded **Co**llar	250
2	**T**able shield	300
3	Shielded **GLa**sses	500
1	**Ce**iling shield	600
4	Shielded **A**pron (total covering)	1750
5+3+4+2	Co+Gla+A+T	2800
5+1+4+2	Co+Ce+A+T	2900
7	Whole body shielded cabin	5667
6	gloves	30000
5+3+4+2+6	Co+Gla+A+T+Glo	32800
5+1+4+2+6	Co+Ce+A+T+Glo	32900

Combinations take care of the substitutability or complementarities

Doing that it appears quickly that the collective shielding are not more costly than most of individual protections (gloves excluded)

Annual costs ranking by increasing cost of combination of options

Having done that it appears quickly that the collective shielding are not more costly than most of individual protections (gloves excluded)

It also appear that most combination of options are quite reasonable in comparison with the annual maintenance cost of the room which is in the order of 70000 € (10% of the initial investment cost)

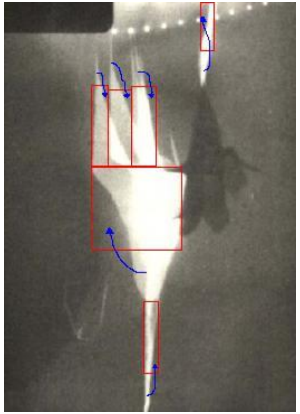
At that stage most options proposed provide quite efficient and not too costly results, but gloves for both criteria

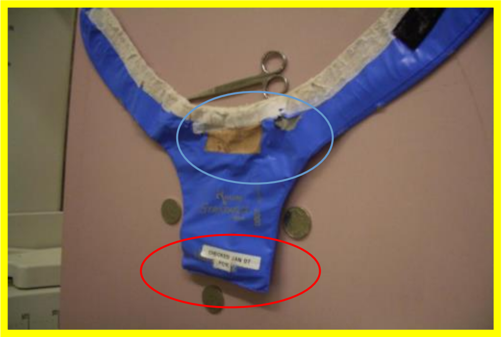
What about the other criteria?

Others Criteria

	Waste	Pain or /and Loss of skill	Impact on patient dose	Improved hygiene
All no cost options	no	no	+++ or no	no
Gloves	- - -	- - -	- -	no
Shielded glasses	-	- -	no	no
Shielded apron	-	-	no	no
Table shield	no	no	no	no
Ceiling shield	no	no	no	no
Whole body shielded cabin	no	+ +	no	++
Shielded collar	-	-	no	-

Sensitivity analysis would make assumptions on





on more or less Regular Testing of Protective Garments which of course will have impacts on cost and efficiency

Take care also of bad cleaning on operating costs

Before

After (a bad) cleaning … 700 € lost!!

Expensive protective apron sent to the cleaning hospital service without the appropriate instructions

Sensitivity analysis should also answer what if…

The number of annual procedures is not 1000 but 2000 or 500 ? What happens if two caths labs perform 500 procedures each and make use of the same individual protection equipments?

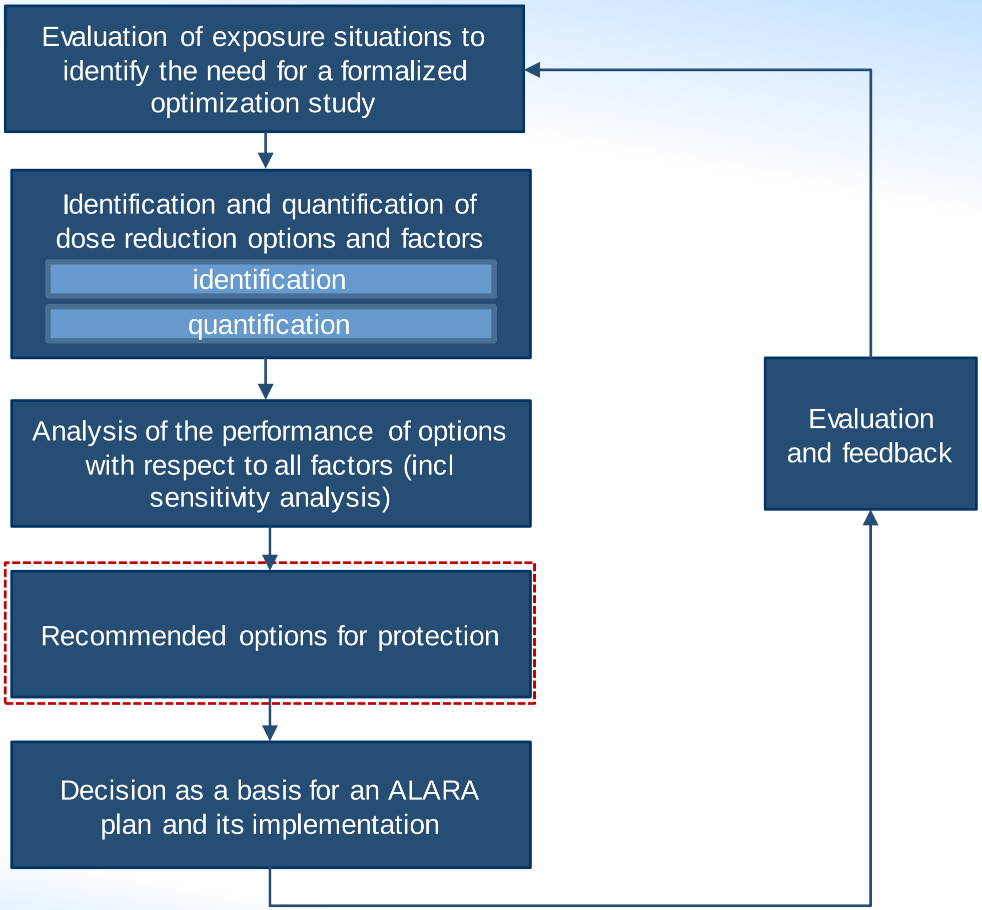
The number of purchased devices per room is not 10 (apron, glasses…) but 5 or 20 ?

The gloves are used 5 times instead of 1

Can you test these hypothesis and see what happens

Does it modify strongly the results or not?

What other hypothesis would you like to modify?


Evaluation of exposure situations to identify the need for a formalized optimization study
Identification and quantification of dose reduction options and factors
identification
quantification
Analysis of the performance of options with respect to all factors (incl sensitivity analysis)
Recommended options for protection
Decision as a basis for an ALARA plan and its implementation
Evaluation and feedback

The recommended options

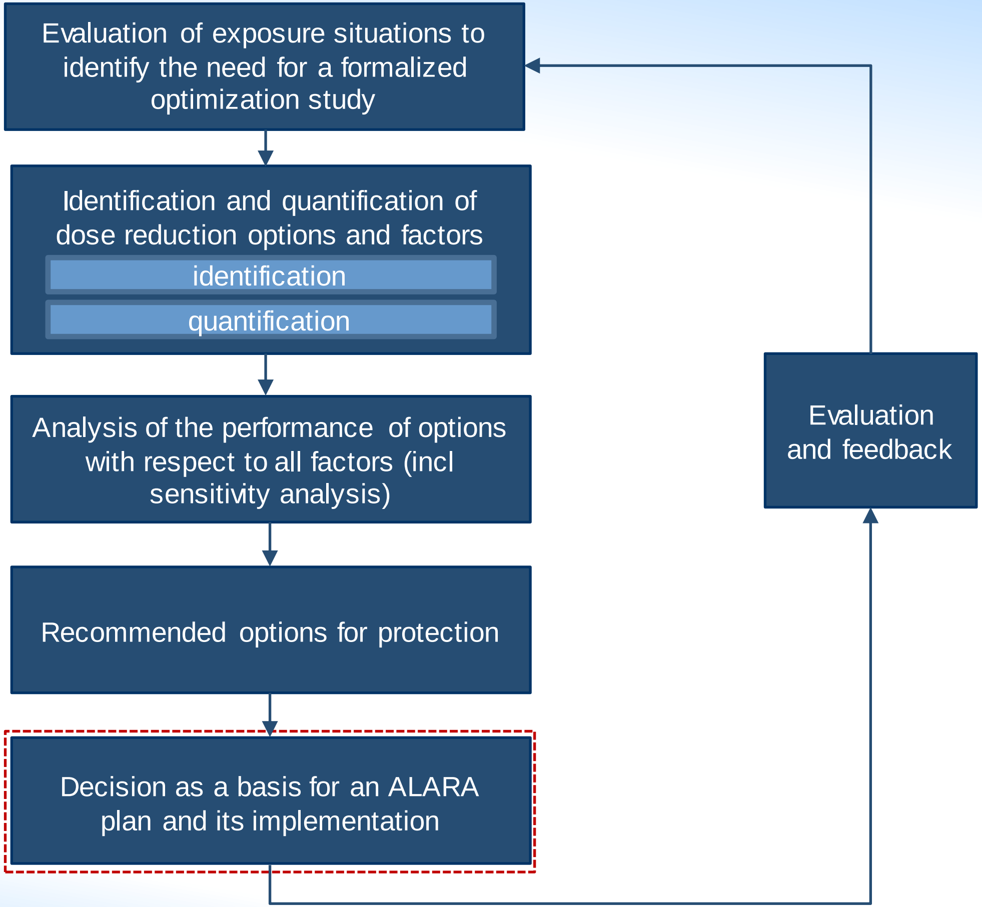
All what is efficient for workers safety, has no cost and no bad impact on patient dose, even the contrary, should be performed and should become the optimisation reference every where : these are just good practices

The collective protective actions should be implemented as they are very cost effective and present no other bad marks

The aprons, thyroid shield are quite evident too, but if the hygiene problem is solved for the second

The cabin may be an extra, depending on the available resources

The use of gloves is neither very interesting in terms of efficiency nor in financial terms


Evaluation of exposure situations to identify the need for a formalized optimization study
Identification and quantification of dose reduction options and factors
identification
quantification
Analysis of the performance of options with respect to all factors (incl sensitivity analysis)
Recommended options for protection
Decision as a basis for an ALARA plan and its implementation
Evaluation and feedback

Optimal decision making

IAEA

Investments for table and ceiling shields should be planned in a radiological protection programme at the hospital level.

Up to the installation of the ceiling shield, lead glasses should be mandatory

Training plans should also be planned to ensure that all cardiologists and workers present in the room are well aware of all the needed actions for protecting themselves and the others, patients included

Routine monitoring programmes for extremities as well as lens should be installed, when available

From time to time RPO' should review the practices and provide feedback on individual practices and evolutions

Optimization procedure and radiation protection programme

The previous case study follow the shape of the optimisation procedure as recommended by ICRP and described in the IAEA Safety Report 21

It allows to illustrate what can be done for facilitating and clarifying the decision making process

But, in order to be efficient, it has to be inserted into a radiological protection programme, where it is clear who makes the decision? in what structure?

Comparison of optimal situation with ISEMIR conclusions

A lot still to be done for convincing and modifying practices

< 24 %

of cardiologists wear two dosimeters in developing countries

< 25 %

wear protective glasses in developing countries versus 50% in other countries

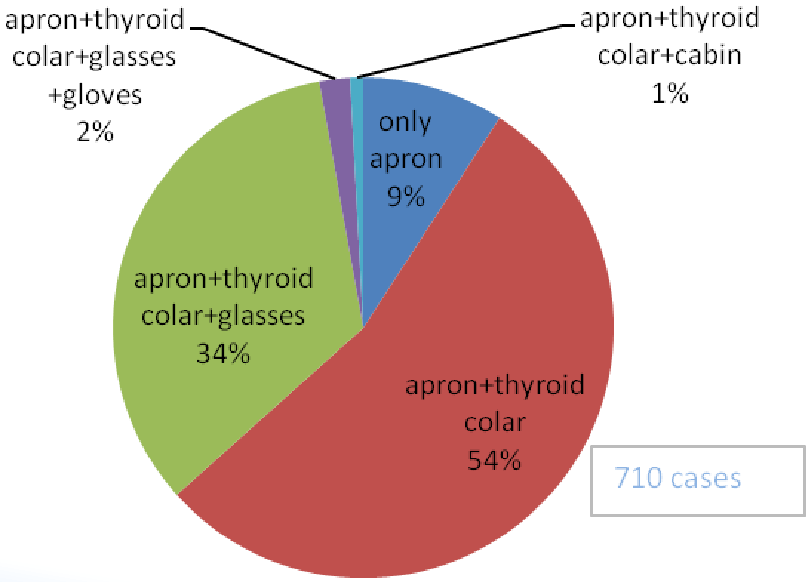
< 77%

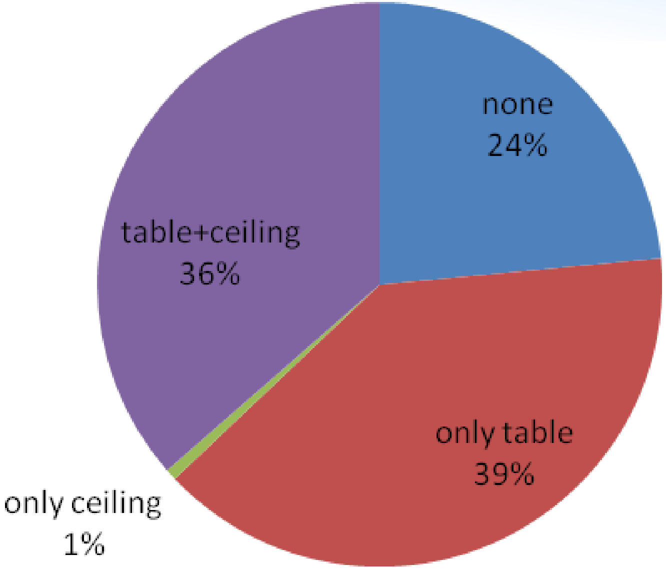
always use a table curtain (coherent with Oramed)

< 78 %

always use a ceiling screen (very optimistic as compared with Oramed)

Comparison of optimal situation with use of personal protective equipment in IC procedures (ORAMED Survey)





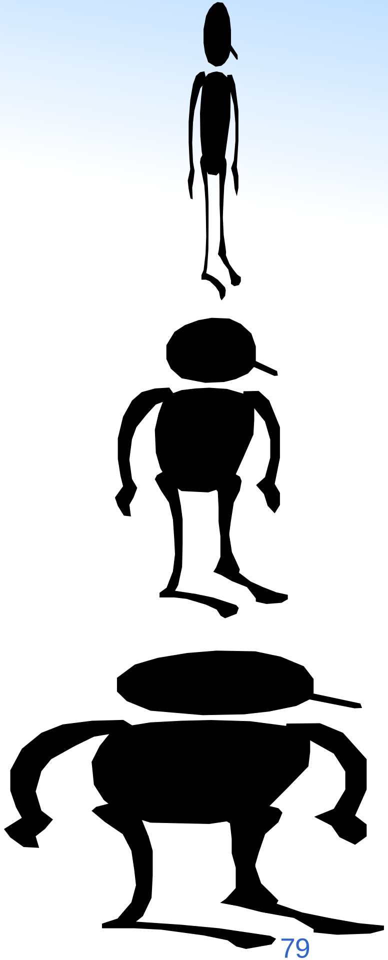
Oramed surveys results

Annexes : to know more about

1. Impact of patient thickness on dose to the IC
2. Efficiency measures of radiological protection options
3. Action levels
4. Oramed recommendations
5. Oramed protocol of measures

Annex 1 influence of patient thickness

Influence of patient thickness: from 16 to 24 cm, scatter dose rate could increase in a factor 5 **(from 10 to 50 mSv/h during cine acquisition)**



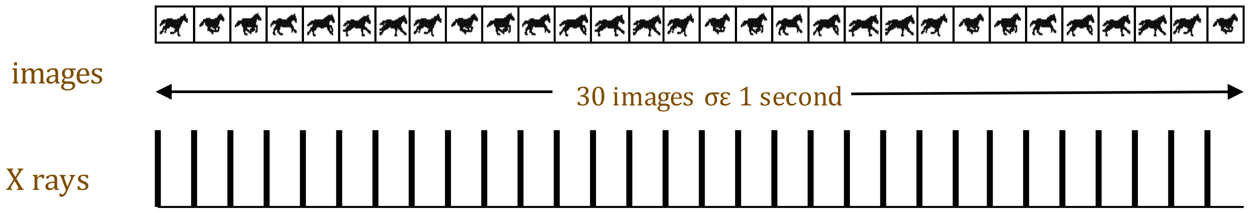
Annex 2: Pulse mode fluoroscopy

The fluoroscopic systems can acquire 25-30 images/sec, which are projected like a “movie”…

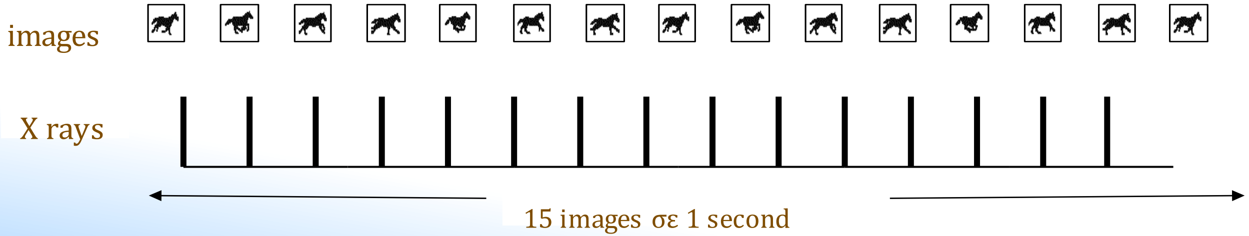
However, due to the continuous irradiation the images are blurred …

Annex 2 Pulse mode fluoroscopy

The *pulsed fluoroscopy* can produce clearer images because each image is produced by a short pulse



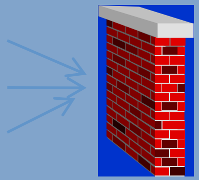
However, there is a choice of reducing the pulse rate and therefore reduce patient and staff doses

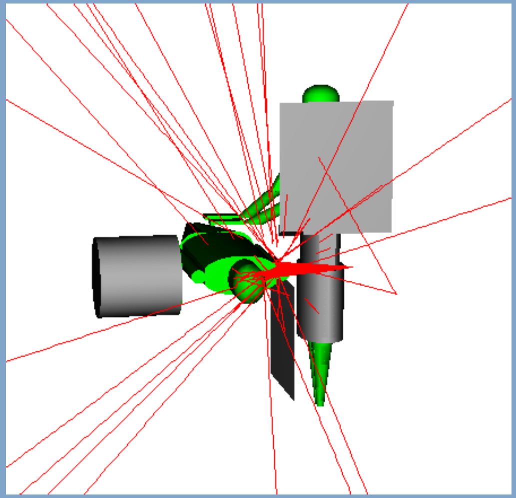


Annex 2 ceiling suspended shield

The eyes are better protected when the shield is positioned more to the side of the operator and not just above the patient. The dose reduction to the left and right eye lens is 93% in this case.

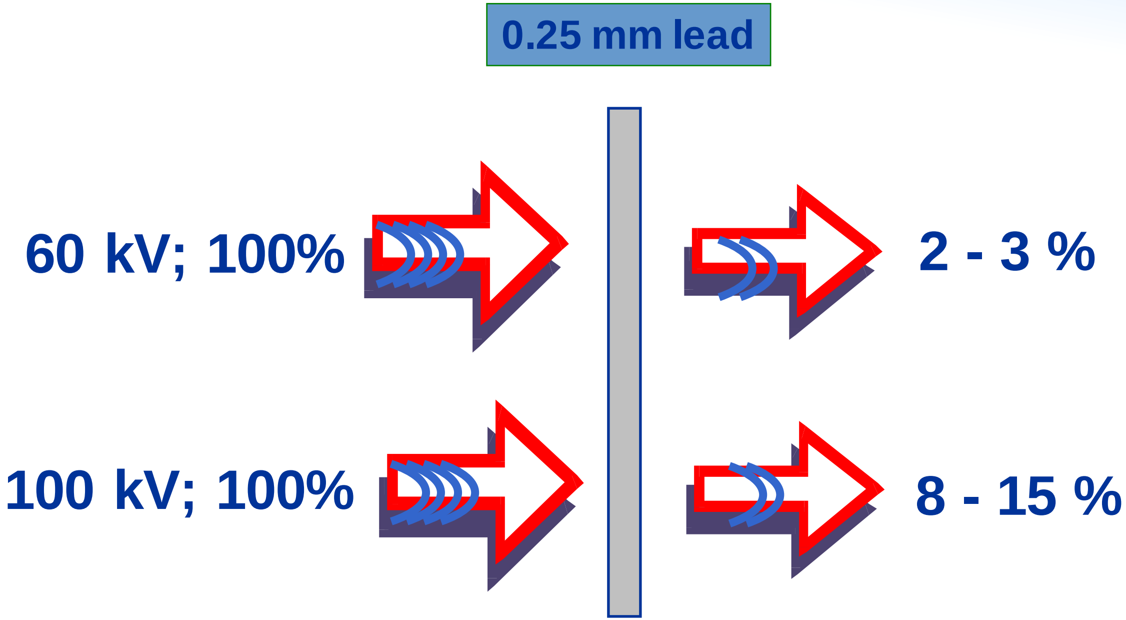
In practice, a second shield is advised especially when biplane technique is used, so that the operator is protected from both X-ray tubes.





ORAMED's measurement campaign

Annex 2: Attenuation measured with lead aprons



X ray beam filtration has a great influence!!

Measurements at San Carlos Hospital, Madrid

Annex 3: suggested action levels

Suggested action levels in staff exposure in interventional radiology
(Joint WHO/IRH/CE workshop 1995)

SUGGESTED ACTION LEVELS FOR STAFF DOSE

Body	0.5 mSv/month
Eyes	5 mSv/month
Hands/Extremities	15 mSv/month

Annex 4 ORAMED Recommendations

Only dedicated interventional radiology *equipment* and *room (properly shielded)* should be used.

Personal protective equipment should be used (at least collar and lead aprons). Lead glasses with side shadow should be preferred.

The room protective equipment should be used and positioned properly.

- Care should be taken for the table shield when assisting personnel stands close to the primary beam or when the operators needs to move around the table for medical reasons.
- The ceiling suspended shield should be placed as close to the patient as possible.
- If biplane systems are used the proper use of lateral shield is very important for the protection of eyes and hands.

Annex 4 ORAMED Recommendations

The tube should be placed below the operating table. The higher doses at the legs in this setup can be reduced by a properly positioned table shield.

The femoral access should be prefered whenever it is possible from medical point of view.

Going outside the operating room during the image acquisition is a practice which can reduce the doses significantly.

Avoiding the direct exposure of hands to primary radiation.

Monitoring of doses to fingers or wrists and eyes should be performed on routine basis .

Annex 4 ORAMED Recommendations

- Routine monitoring of doses to hands or wrists as well as to the eye lens.

✓In the procedures that were examined the left wrist was found to be the position with the maximum dose and then the left finger (for embolizations, DSA PTA LL and pacemakers). Generally, the maximum doses were measured at the left wrist for the femoral access and at the left finger when the radial access is used or when the operator’s hands are very close to the beam field. However, when the annual limits are taken into account the maximum exposure is observed for the eyes for most of the procedures (the exception are Pacemaker and CA PTCA procedures). **So ring or wrist and eye lens dosimeters are important for routine monitoring.**

	Percentage of Annual limit [%]										
	(0-10>	(10-20>	(20-30>	(30-40>	(40-50>	(50-60>	(60-70>	(70-80>	(80-90>	(90-100>	>100
Finger	77,8%	9,9%	6,2%	1,2%	1,2%	0,0%	0,0%	0,0%	0,0%	0,0%	**3,7%**
Wrist	77,1%	9,6%	7,2%	2,4%	0,0%	3,6%	0,0%	0,0%	0,0%	0,0%	0,0%
Leg	82,1%	8,3%	6,0%	0,0%	0,0%	1,2%	1,2%	0,0%	0,0%	0,0%	**1,2%**
Eye	75,0%	9,5%	7,1%	2,4%	3,6%	1,2%	0,0%	0,0%	1,2%	0,0%	0,0%

Annex 5 Oramed protocol

No…………

MEASUREMENT PROTOCOL

Date ……………………

Hospital : ____________________
System / Detector : ____________ Tube Above/Below: ________
Procedure : ____________________
Physician (initials) : ____________________

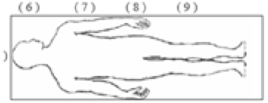
1. PROTECTIVE EQUIPMENT

		mm Pb
Lead Apron		
Thyroid Collar		
Eyewear		
Lead Gloves		
Table Curtain		
Patient Shield		
Ceiling		
Floor		

2. STAFF POSITION

Number of persons in the room / position[1]

MDs : A ____ B ____ C ____
Techn.: A ____ B ____ C ____
Nurses: A ____ B ____ C ____
Others: A ____ B ____
Access [2] (R / F / P / IJV) ____



3. GENERAL PARAMETERS

FSD[3] ____
FDD[3] ____
FOV ____
ZOOM ____
Biplane (Y/N) ____ Tube 1 Tube 2
DAP present (Y/N)? ____

4A. FLUOROSCOPY

Projection[4]					
kV					
mA					
Pulses/s					
Pulse duration ms					
Filtration mm Cu					
Mode					

B. CINE

Projection[4]					
kV					
mA					
Frames/s					
No of Frames					
Pulse duration ms					
Filtration mmCu					
Mode					

No…………

5. DAP VALUES (units: ……..)

FLUORO : ____ Fluoroscopy Time (…….) : ____
CINE : ____ Total Frames Acquired : ____
TOTAL : ____

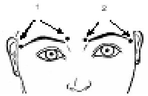
6. OTHER REMARKS

Body part irradiated : ____ Physician's Height : ____
Patient size (child / S / M / L) : ____ Complexity of procedure (Low / Medium / High) : ____
Physician's experience (Low / Medium / High) : ____ Physician's Dominant Hand (R / L/ Both) : ____

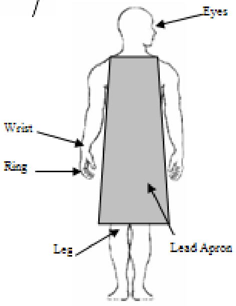
COMMENTS: ____________________

7. TLDs – MEASURING POINTS - RESULTS

TLD type : ____
Number of TLDs : ____



TLD positions	Pellet No R	Pellet No L	Measured Dose (mSv) R	Measured Dose (mSv) L
1. Ring finger[5]				
2. Wrist[6]				
3. Leg[7]				
	Middle	R/L side	Middle	R/L side
4. Eyes[8]				



ORAMED measurements in IR/IC/ICIC