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Radiation protection in the cathlab: optimization and practical tips

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Overview

- Optimization of Protection in Fluoroscopy
 - Radiation protection rules
 - Practical implementation in the cathlab
 - Radiation protective equipment and shielding
 - New imaging technology
- Staff doses
 - Factors affecting staff doses
 - Dose monitoring
 - Eye lens doses and leaded eyewear
 - Example of effect of a dose reducing technique on staff dose

Optimization of protection in fluoroscopy

Interventional cardiological, electrophysiological and radiological procedures (CA, PTCA, RF ablations, ICD, DSA, PTA, embolisations,...) are high-dose procedures (1-100 mSv/h scattered dose rate @30 cm from patient)

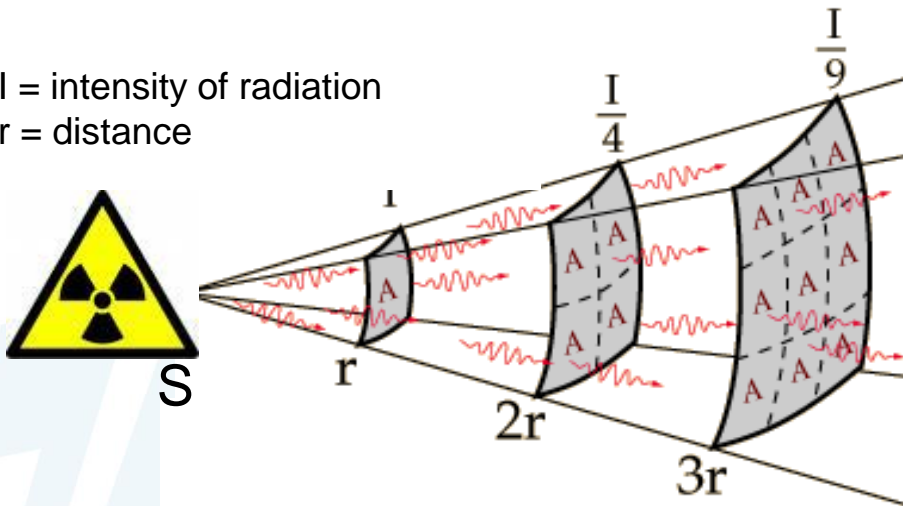
- Both physical and technical parameters may have an influence on patient and staff dose.
- Good radiation protection policy and personnel skill are essential for reducing both staff and patient exposures.



Basic radiation protection rules

1. Increase distance-to-source

I = intensity of radiation
 r = distance



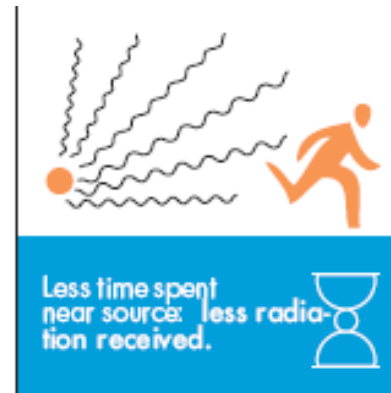
Inverse square law

The energy twice as far from the source S is spread over four times the area A , hence $I/4$

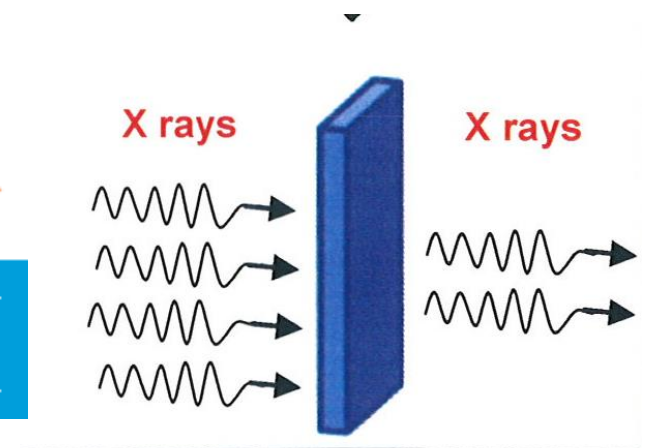
Occupational exposure can vary from very low levels to levels close to the legal limit value (Doses of interventional radiologists and cardiologists are among the highest in the clinic)

⇒ **Need for a radioprotection plan and dose reducing measures i.f.o. type of radiological procedure**

2. Minimize exposure time



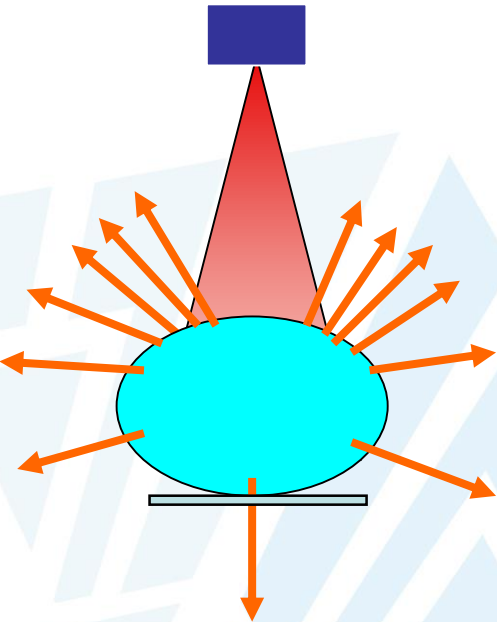
3. Use appropriate shielding



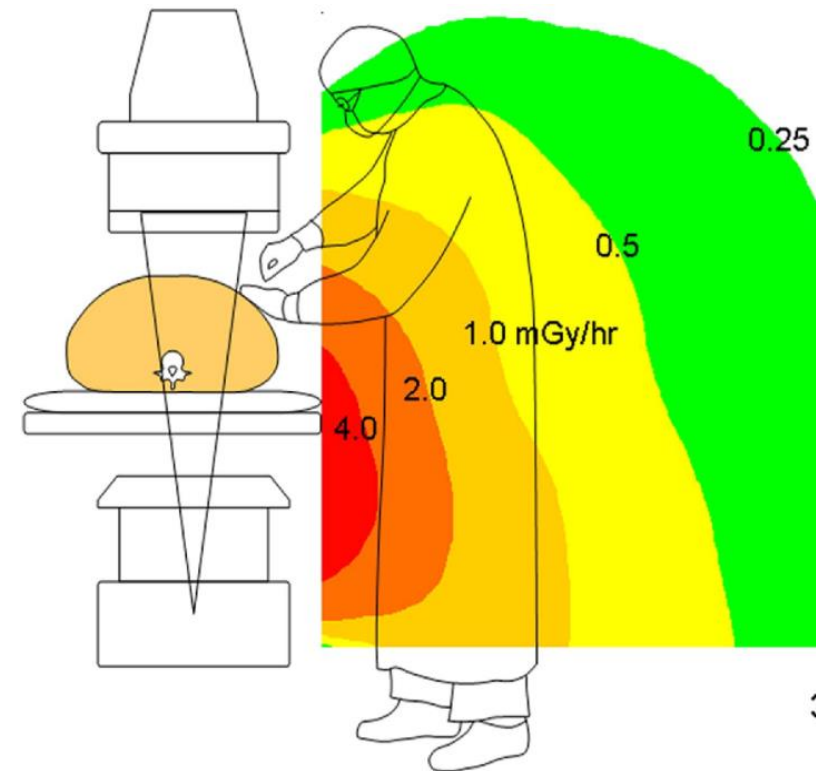
Basic radiation protection rules

In the **cathlab** medical staff is mainly exposed to scattered radiation coming from the patient.

Rule of thumb: For every 1000 photons reaching the patient, about 100-200 are scattered, about 20 reach the image detector, and the rest are absorbed (contributing to patient dose)



- Scattered X-rays also obey the Inverse Square Law, so distance from the patient reduces the staff dose
- Scattered radiation is not uniform around the patient
- The dose rate around the patient is a complex function of a great number of factors



Scattered radiation

1) Is proportional to the primary beam

If patient dose increases by factor 2, than staff dose will also increase (more scattered radiation).

⇒ Use appropriate parameter settings (kV,mA,pulse/s,...) i.f.o. required image quality!

2) correlates with the exposed area of the patient

Scattered dose rate is lower when field size decreases

⇒ Collimate the X-ray beam to the area of interest

e.g.: Skull phantom (Ref.<http://www.upstate.edu/radiology/education/rsna/fluoro/collimation/>)



Figure T

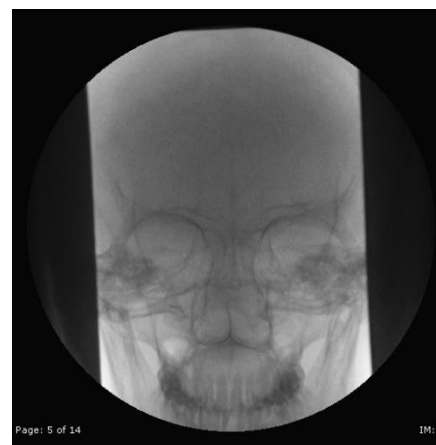
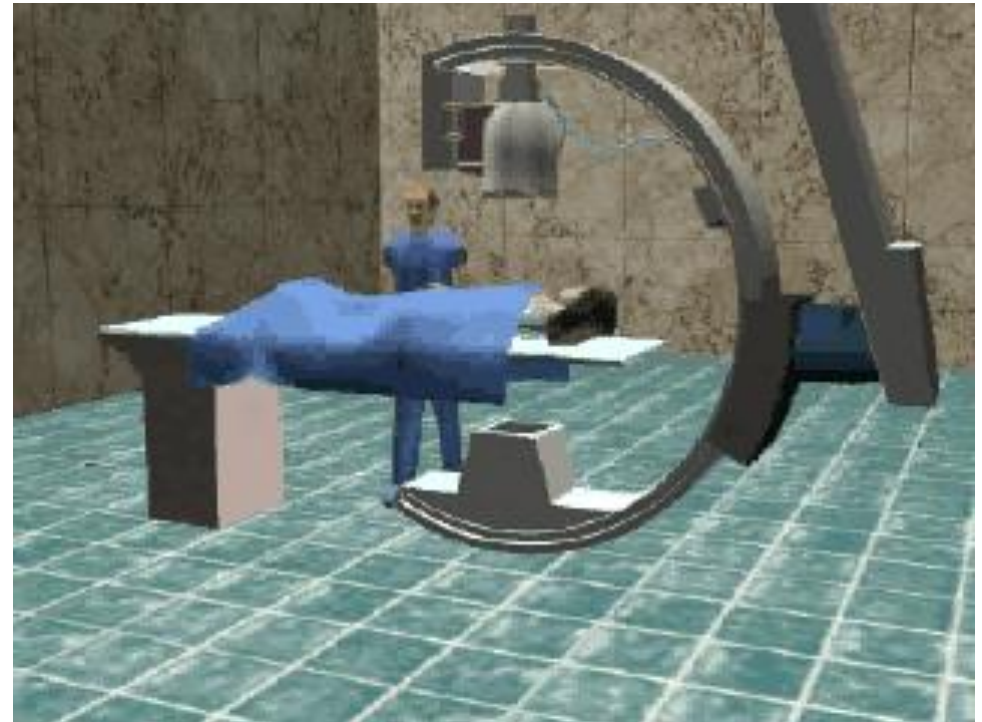


Figure U

Scattered radiation

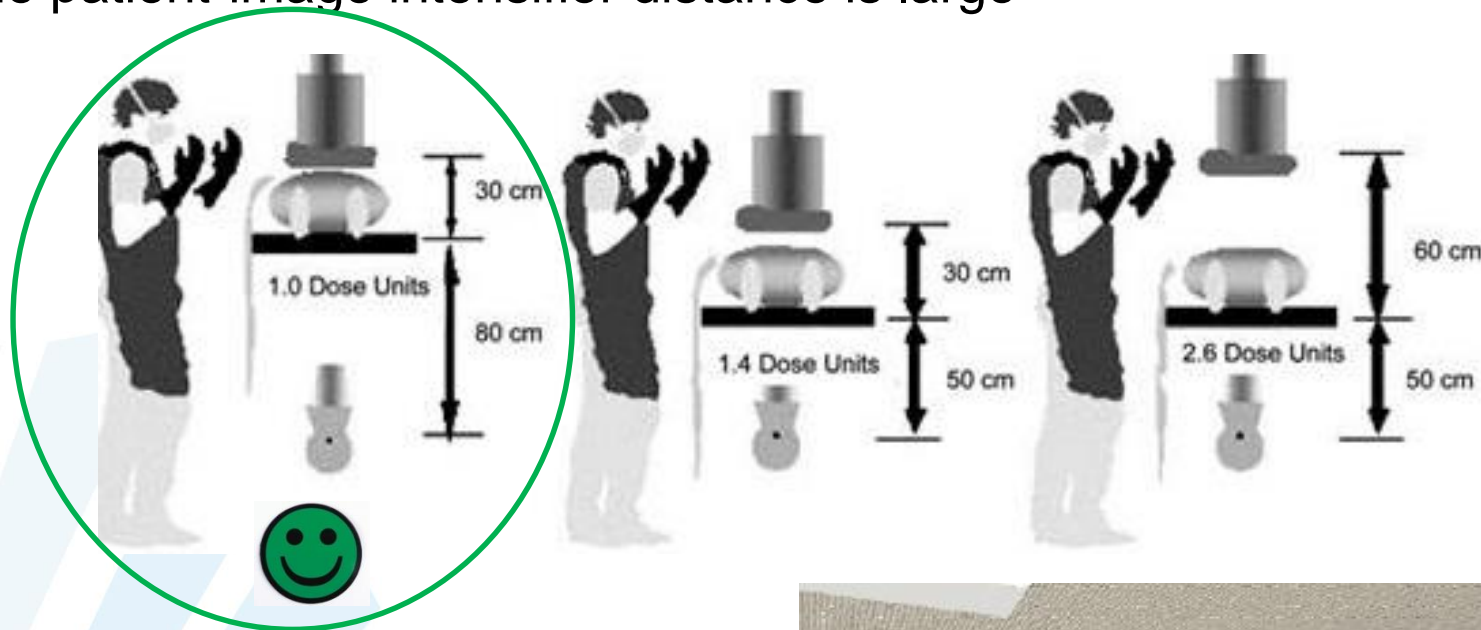
- 3) Scattered radiation is not uniform around the patient but is mainly directed towards the source
- ⇒ Use Tube-under-couch-position (X-ray tube under the patient at vertical stand)
 - ⇒ Stand at the image intensifier side when the C-arm is placed horizontally.
 - ⇒ Angle dependence: Scattered dose rate is higher near the area where the X-ray beam enters the patient



Projection stand of X-ray tube and image intensifier

Patient dose and scattered radiation will increase if:

- The Source-to-Skin Distance is short
- The patient-image intensifier distance is large



Position of the screens



Practical implementation in the cathlab

Lengthy and complex procedures → Prolonged exposure time

Operating staff very close to the patient → Shielding possibilities i.f.o. specific procedure

Golden Rules:

- Keep your distance, as far as is practicable
- Keep the image intensifier close to the patient and the X-ray tube at maximal distance from patient
- Do not overuse magnification modes: decreasing FOV by factor :2 increases dose rate by factor x4
- Adjust parameter settings i.f.o. procedure and patient (adult vs. child; patient weight; ciné mode,...)
- Prefer pulsed fluoroscopy (with the lowest frame rate possible for acceptable image quality)
- Use ciné mode only where necessary (Cine dose rate \approx (10-60) \times normal fluoroscopy dose rate)
- Use personnel protective equipment and know where scatter is highest

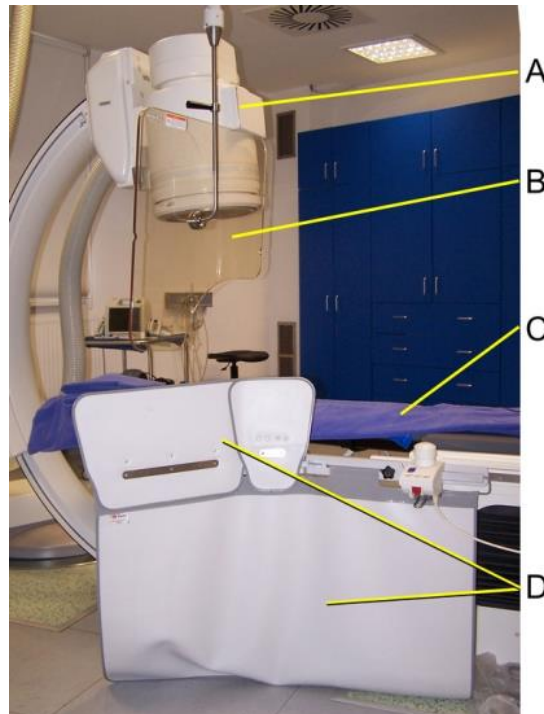


Personnel protective equipment and use of shielding

Shielding infrastructure: lead shielding in walls and doors, leaded glass, concrete floor/ceiling

Shielding of the operator: lead apron and collar, leaded eyewear

Protective equipment: table lead curtains (D), ceiling mounted screens (B), lead drapes (C), mobile lead screens (E), radiation protection cabin (F)



E

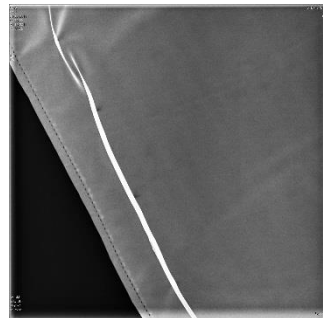


F

Personnel protective equipment



- Wear a lead collar to protect the thyroid (radiosensitive organ)
- Staff standing very close to the patients are advised to wear lead glasses
Whether it is mandatory depends on the workload, type of procedure and position of the operator. Your radiation protection officer can give detailed advise, also based on the dose results above the lead apron (as a first approximation of the eye lens dose).
- Wear a lead apron that fits – a vest/skirt model with overlap is preferred
 - Better ergonomics
 - Overlap gives extra protection frontally
- Make sure the “zero lead” aprons are tested properly for their shielding power - seek advice from your RPO when in doubt
- Regular control (e.g. annual) for damage of lead apron and collar
Inspect with fluoroscopy/radiography for tears, holes in the lead protection
To prevent damage, do not fold but store the apron on a hanger



New imaging technologies

Standardized comparative safety analysis of various X-ray systems currently used in the cathlab

Reference: Christopoulos *et al*, Catheterization and Cardiovascular interventions 86:927-932 (2015) wileyonlinelibrary.com

Conclusion: Significant differences in patient radiation dose with different X-ray systems used in standardized settings

New imaging processing and noise reduction technology allows reduction of radiation exposure

Reference: Dekker *et al* Heart Rhythm 10: 1678-1682 (2013)

Conclusion: New imaging technologies and dose optimization protocols can reduce patient and personnel dose

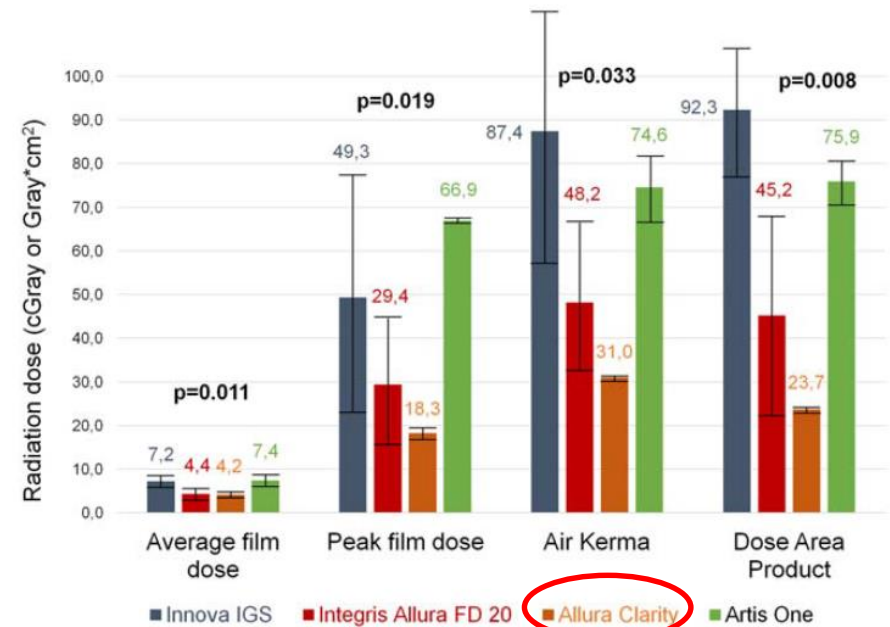


Fig. 3. Comparison of average film dose, peak film dose, and AK dose between the four X-ray systems. Error bars represent standard deviation. P values denote the results of the Kruskal-Wallis test comparing the four X-ray system means.

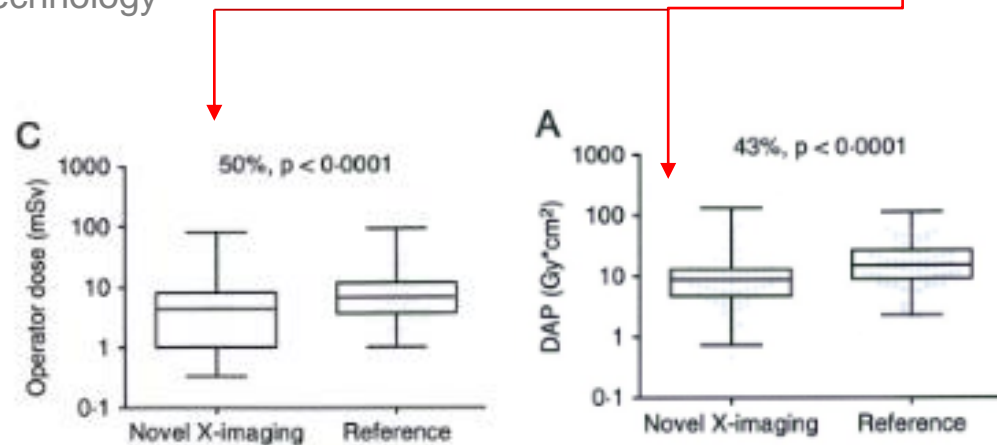
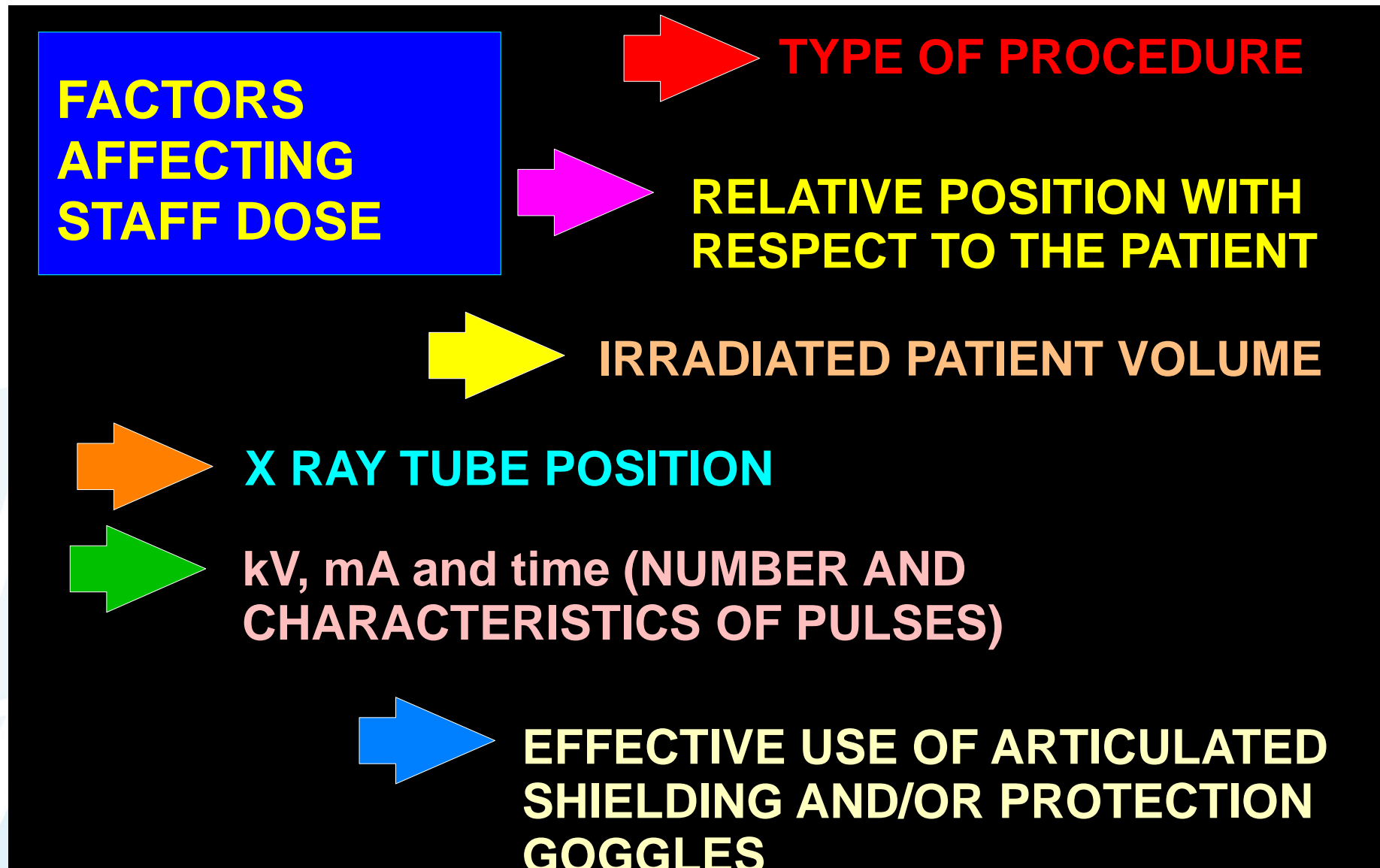
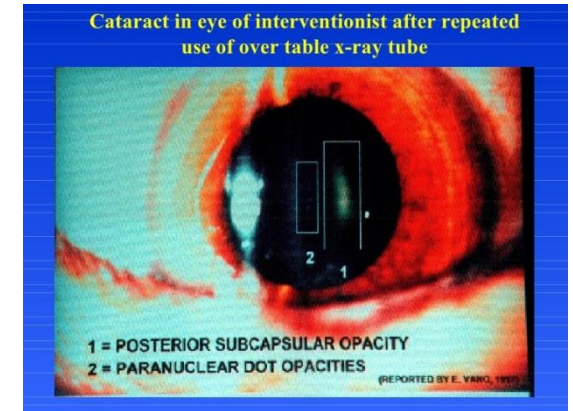
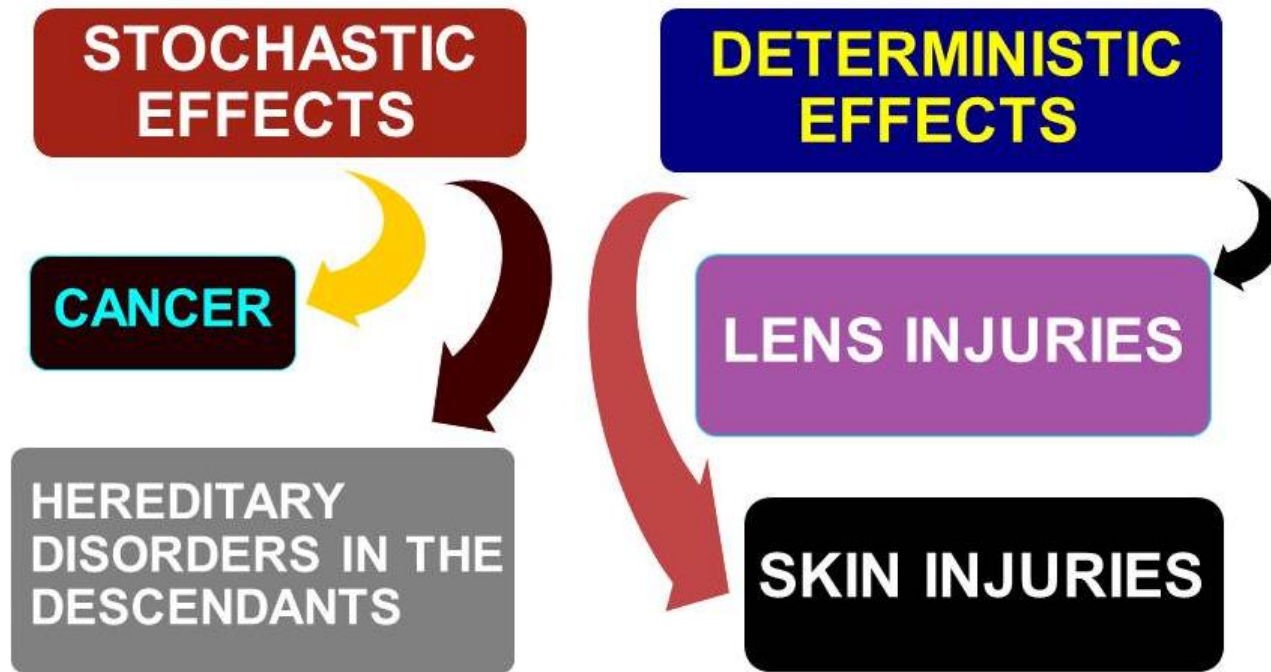


Figure 2 Box and whisker plots with overlaid scatter plot data for procedural dose area product (DAP) (A), air kerma (AK) (B), and operator dose (C) on a logarithmic scale. D: Mean and SD for fluoroscopy times. Box illustrates median and interquartile range; whiskers illustrate maximum and minimum values.

Factors affecting staff doses



Radiation effects on humans

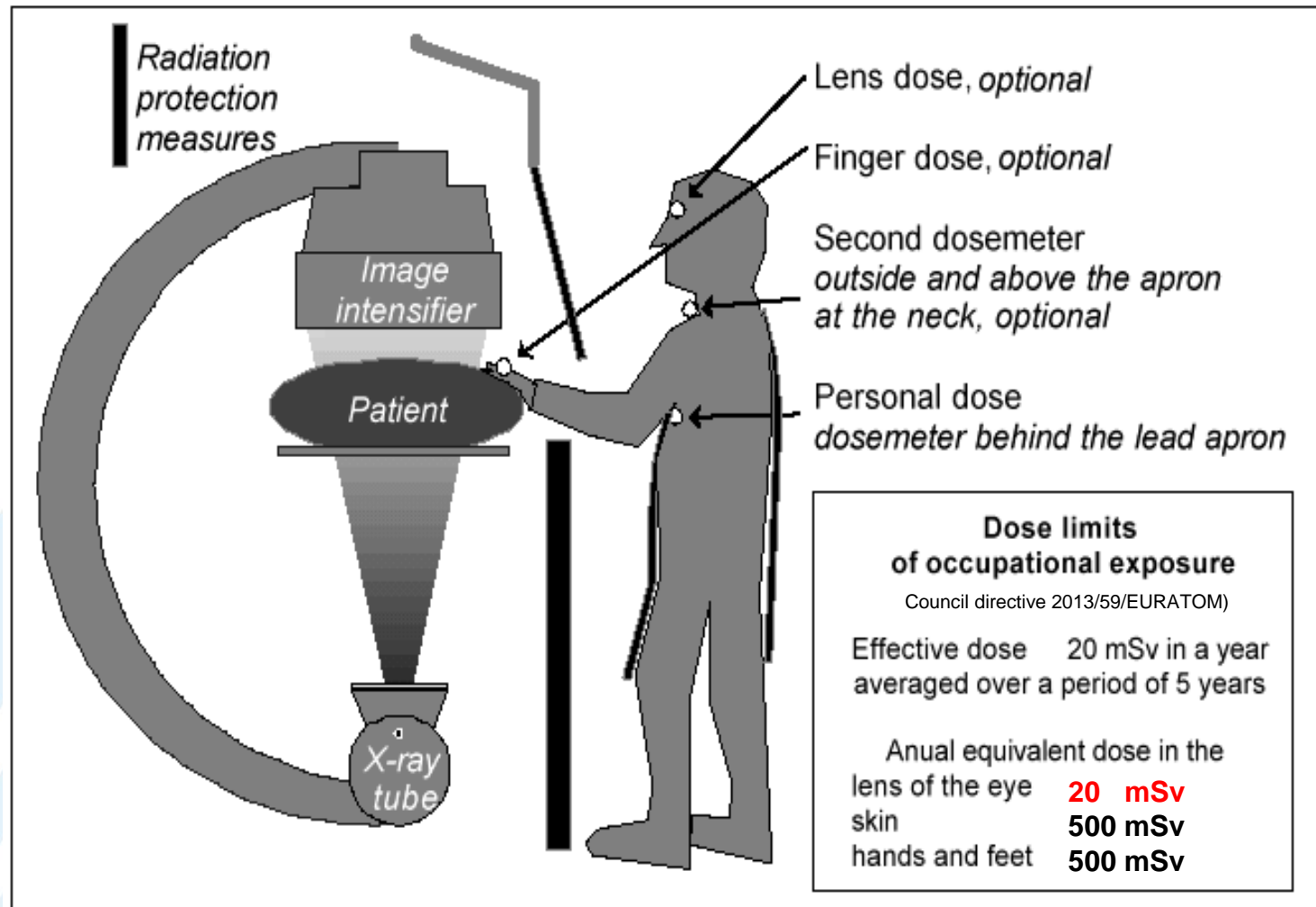


Staff doses can be reduced by **reducing patient dose** and **good radiation protection policy**

The correct use of equipment (including shielding devices) is essential:

- Modern sophisticated X Ray systems
- Use of protection tools, leaded , specific shielding, etc
- Suitable knowledge of the system**
- Skill, rational (shared) workload**

Personnel dose monitoring



“Interventional radiology departments should develop a policy that staff wear two dosimeters” (ICRP 85)

ARBIS: When there is a possibility that 3/10th of the legal dose limit is exceeded, extra dosimeters should be worn for a more precise estimation of the exposure

Eye lens doses and leaded eyewear

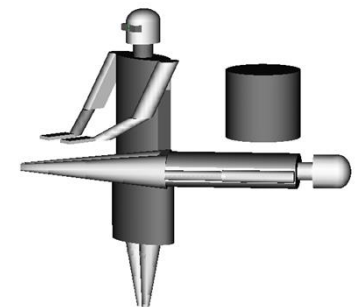
- Protection of the eye lens does not only depend on Type of protection device (leaded eyewear, leaded ceiling screens) But also on how they are used and the work procedure
- Protection efficiency of lead glasses increases if the head is faced towards the X-ray source
(more frontal collision of the scattered radiation upon the glasses)

BUT
Eye lens dose lower when operator is turned away from the X-ray source (with and without leaded glasses!)

Good practice: Always wear **lead glasses with side protection**

Lead thickness: 0,35-0,5 mm Pb_{eq}

A good fit is essential: no big gaps between face and lead glasses



Eye lens doses and ceiling lead screens

Whenever possible use ceiling mounted lead screens

Advantages :

- lead thickness of 0,5-1,5 mm
- an average protection efficiency of 45%
- protects entire face, trunk and hands (correct usage)
- no personal discomfort (the use of lead glasses can cause headache, reduced view due to condensation of the glasses,...)

Good practice:

Place protective screens always as close as possible to the X-ray device and the patient (radiation source)

Biplane systems: place an extra protective screen laterally or use a radiation protection cabin

Correct use is important!



Overview of staff doses

UZ Leuven, 2014 – registered (H_{p10}) dual dosimetry - yearly dose/individual

<u>Category/department</u>	<u>Dose range (min – max)</u>
interventional radiologists and cardiologists:	5 mSv - 10 mSv
nursing personnel cathlab:	0 mSv - 4 mSv
radiology department:	0 mSv - 1 mSv
nuclear medicine department	0 mSv - 6 mSv



Effect of new imaging technique on staff dose IR UZ Leuven

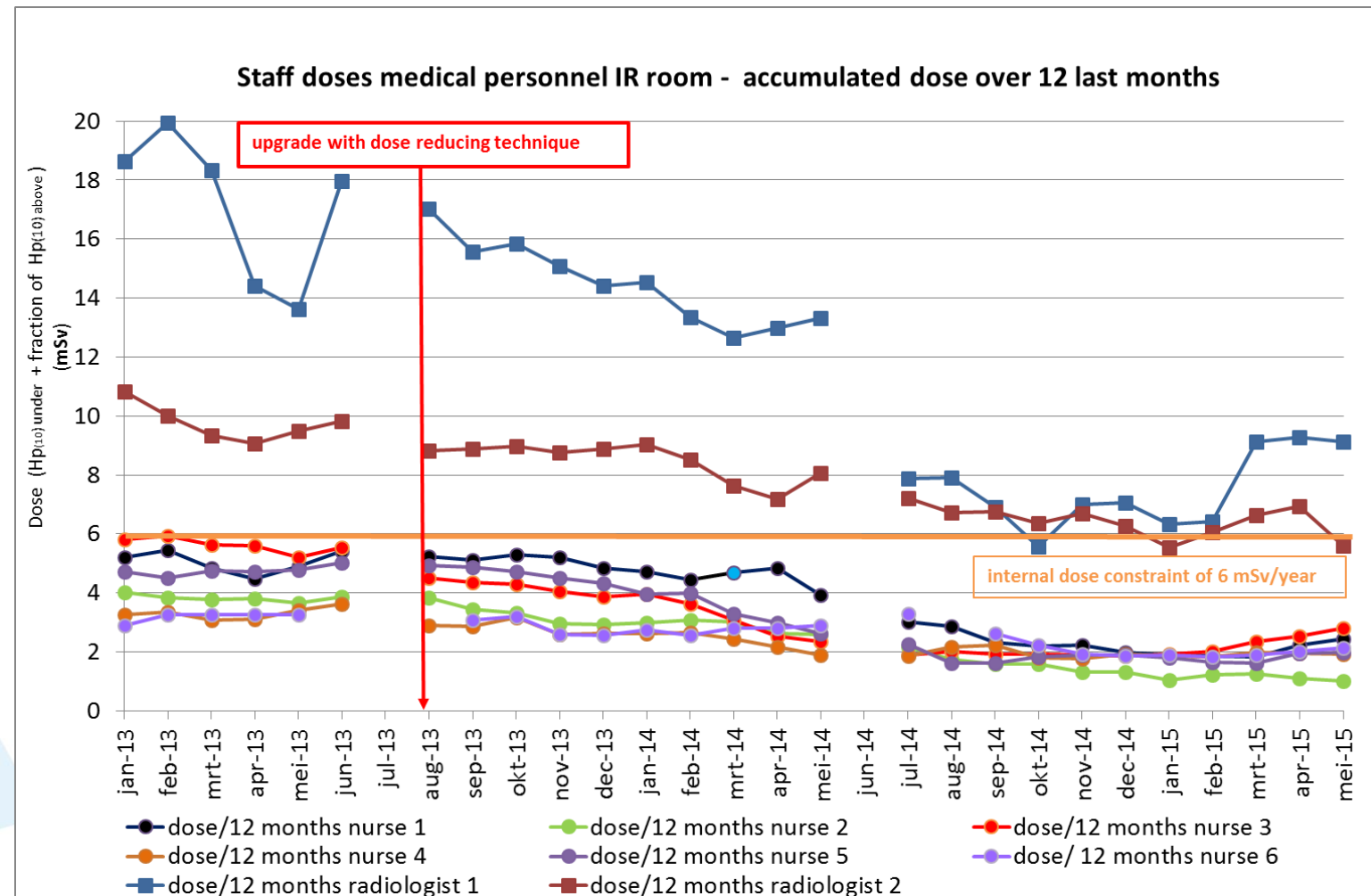
Introduction of Philips Allura Clarity (dose reducing system) August 2013

Allura XPER FD20, ciné mode (75 kV, 47 mAs/puls): 310 mSv/h @50 cm

Allura Clarity, ciné mode (75 kV, 47 mAs/puls): 20 mSv/h @50 cm

Dose rate measurements of scattered radiation: ↓ factor 10

Also a reduction in all staff doses visible in the monthly dose registration!



Importance of regular QC and optimization of the clinical procedures/imaging techniques
 → Good collaboration between IR/IC staff, medical physics and radiation protection personnel

Reduction of patient dose also reduces personnel doses!

Thank you!

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References:

ICRP, 2013. Radiological protection in cardiology. ICRP Publication 120. Ann. ICRP 42(1)

ICRP, 2007. ICRP Publication 103

IAEA radiation protection for patients <https://rpop.iaea.org/>

IAEA Training Material on Radiation Protection in Diagnostic and Interventional Radiology

ORAMED <http://www.oramed-fp7.eu/>

Struelens Lara, SCK, Eye lens doses for medical staff performing interventional procedures, 2013

Videofragments: http://ec.europa.eu/energy/nuclear/radiation_protection/medical/publications_en.htm

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Useful information:

http://www.fanc.fgov.be/nl/page/profiel-rontgentoepassingen-buiten-de-dienst-radiologie/1402.aspx#P_6093

<https://rpop.iaea.org/RPoP/RPoP/Content/index.htm>

http://eman-network.eu/IMG/pdf/C-bue_poster_dutch.pdf