International Conference on Occupational Radiation Protection

Vienna, 4th December 2014

Occupational radiation protection in interventional radiology

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International Commission on Radiological Protection, C3

The benefits of x-ray guided interventions

- A number of pathologies, formerly requiring major surgery, can now be treated with minimally invasive x-ray guided interventions
- In addition, some lesions, that are not accessible to surgery or non-operable pathology can also be treated this way

The intervention requires

- X-ray imaging:
  - To conduct the catheter or other tools through a small incision towards the pathological area
  - To perfom the therapeutic intervention under x-ray control
  - To document the result of the intervention for follow up

Normally, fluoroscopy lasts a few minutes

- But the intervention can become complicated when the pathology is complex and
- Thus, imaging lasts longer and the exposure can become high
- And can exceed the threshold for tissue reaction on patients
- In some extreme cases, when these circumstances are combined with non-optimized protection, the injuries can be severe, resulting ulcerations and necrosis on the patient skin

Not only the patient, but also the staff, is exposed to high doses

- Occupational exposure of interventionalists is among the highest occupational exposure of all medical use of radiation
- Radiation doses to the eye lenses of interventional staff with high workloads can routinely exceed the new limit unless appropriate radiation protection measures are put in place
- And radiation-induced eye lens opacities in some professional groups has been observed
- High doses to hands and legs and hair loss in unshielded portions of legs has also been reported

A variety of professionals involved in fluoroscopically guided procedures, some of them with no previous training on radiation protection

- Cardiologists
- Gastroenterologists
- Neurologists
- Urologists
- Paediatrists
- Anaestesiologists
- Orthopaedic surgeons, traumatologists
- Other surgeons …

Trend

- Increased frequency, fast growth
- New types of procedures, with new benefits but increased complexity and thus higher exposure

ICRP working party

Occupational radiation protection issues of fluoroscopically guided interventions

Preliminary draft

Members of the working party

Members

- P. Ortiz (WP Chair), C3
- E. Vañó, C3
- D. Miller, C3
- C. Martin, C3
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Corresponding members

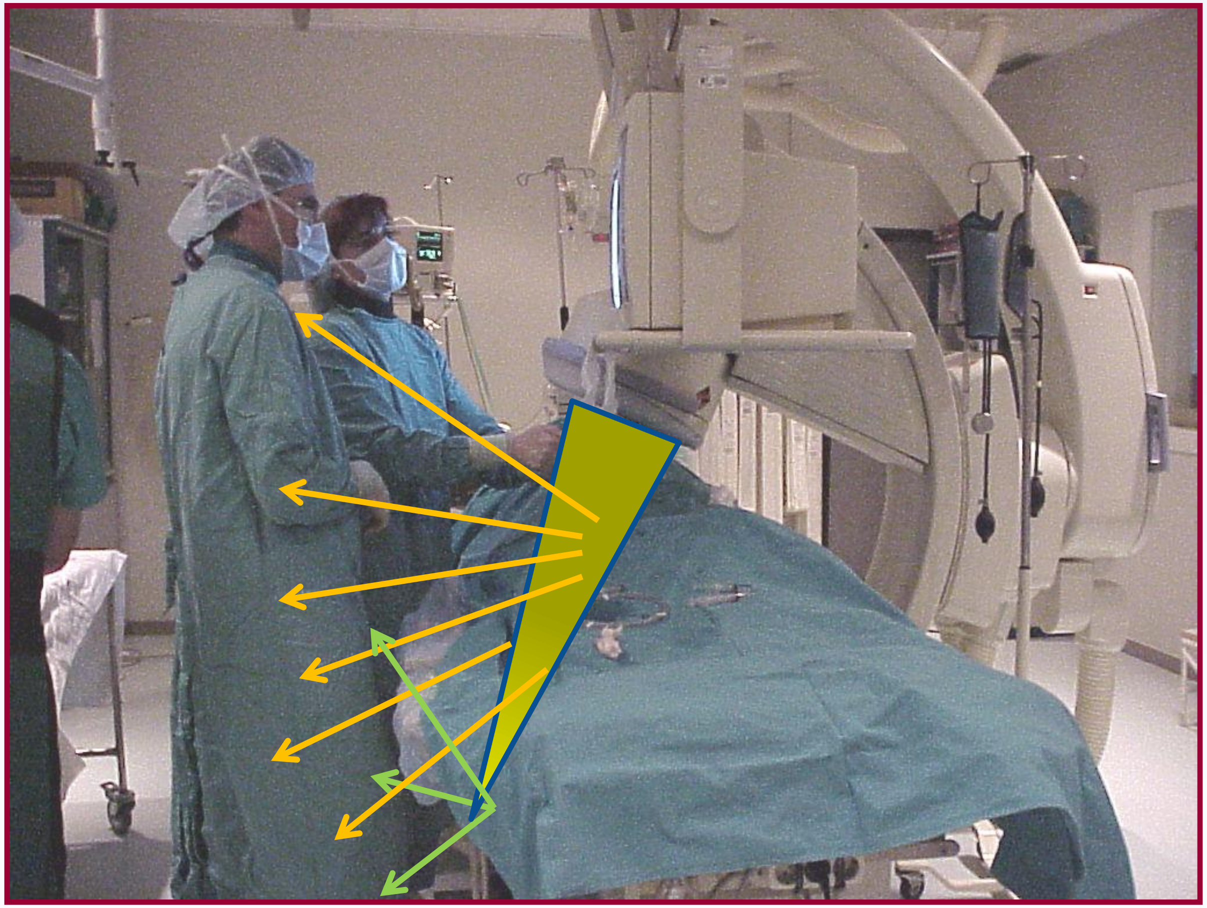
- M. Doruff, C4
- R. C. Yoder, Illinois, USA
- R. Padovani, Italy

Summary

- Level of exposures
- Exposure monitoring and assessment
- Protective approaches

Occupational exposure

- The primary beam is not directed to the staff
- Radiation scattered by patient and couch
- Leakage radiacion from the x-ray tube

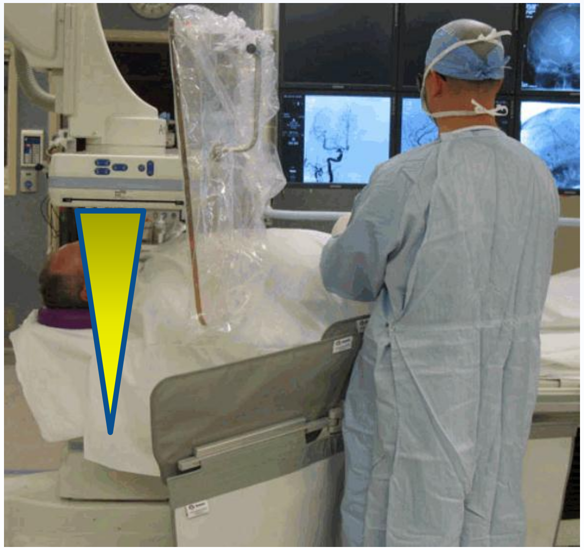


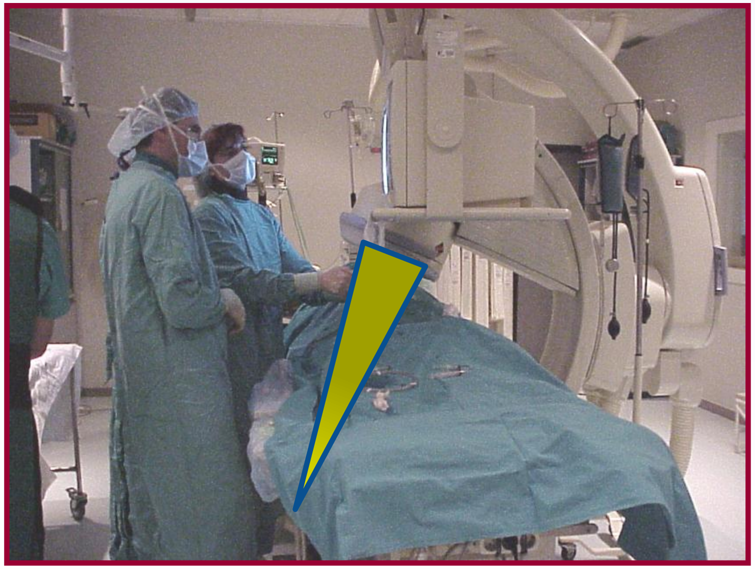
Effective doses

- Interventionalists with proper radiation protection devices and techniques may keep their annual effective doses below 10 mSv, and typically within a range of 2 to 4 mSv (Miller 2010),
- However, surveys have shown that individual occupational doses may be higher (Padovani 2011)

Hand doses

- Doses to the hands depend on the distance to the primary beam
- Normally, the hands are not inside the beam and thus they receive only scattered radiation;
- Some times the hands may fall into beam for certain moments



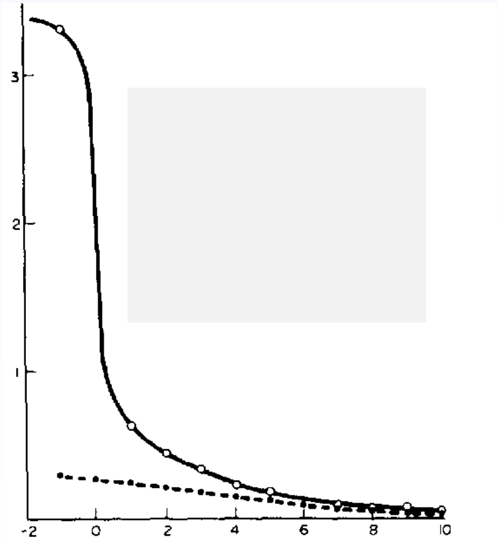


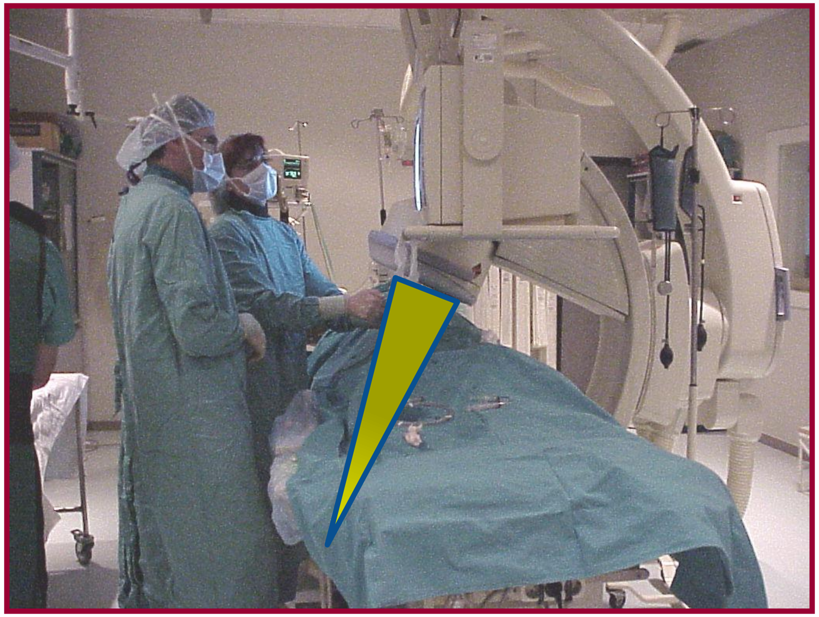
Example

- In interventions on the upper abdomen with the hands close to the beam (example transhepatic cholangiograms and biliary and nephrostomy procedures) and average hand dose of 1.5 mGy per intervention has been shown (Femlee et al., 1991)

Hand doses when in the beam

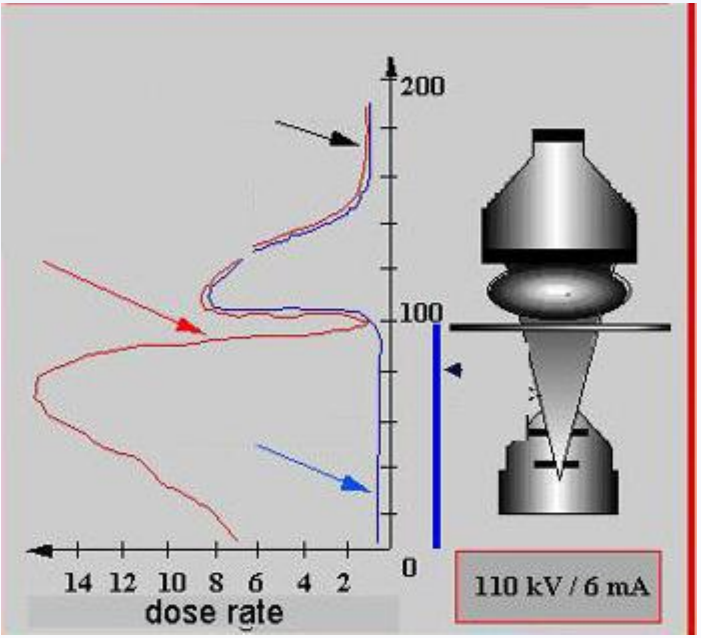
- In an x-ray undercouch geometry, the dose rate in the beam transmitted through the patient would be typically 2 to 5 μGy s^{-1}
- But, in an overcouch x-ray tube, direct exposure to the incident primary beam from an could be 50-100 times greater.
- Therefore, configurations with the x-ray tube above the patient are not adequate for x-ray guided interventions.



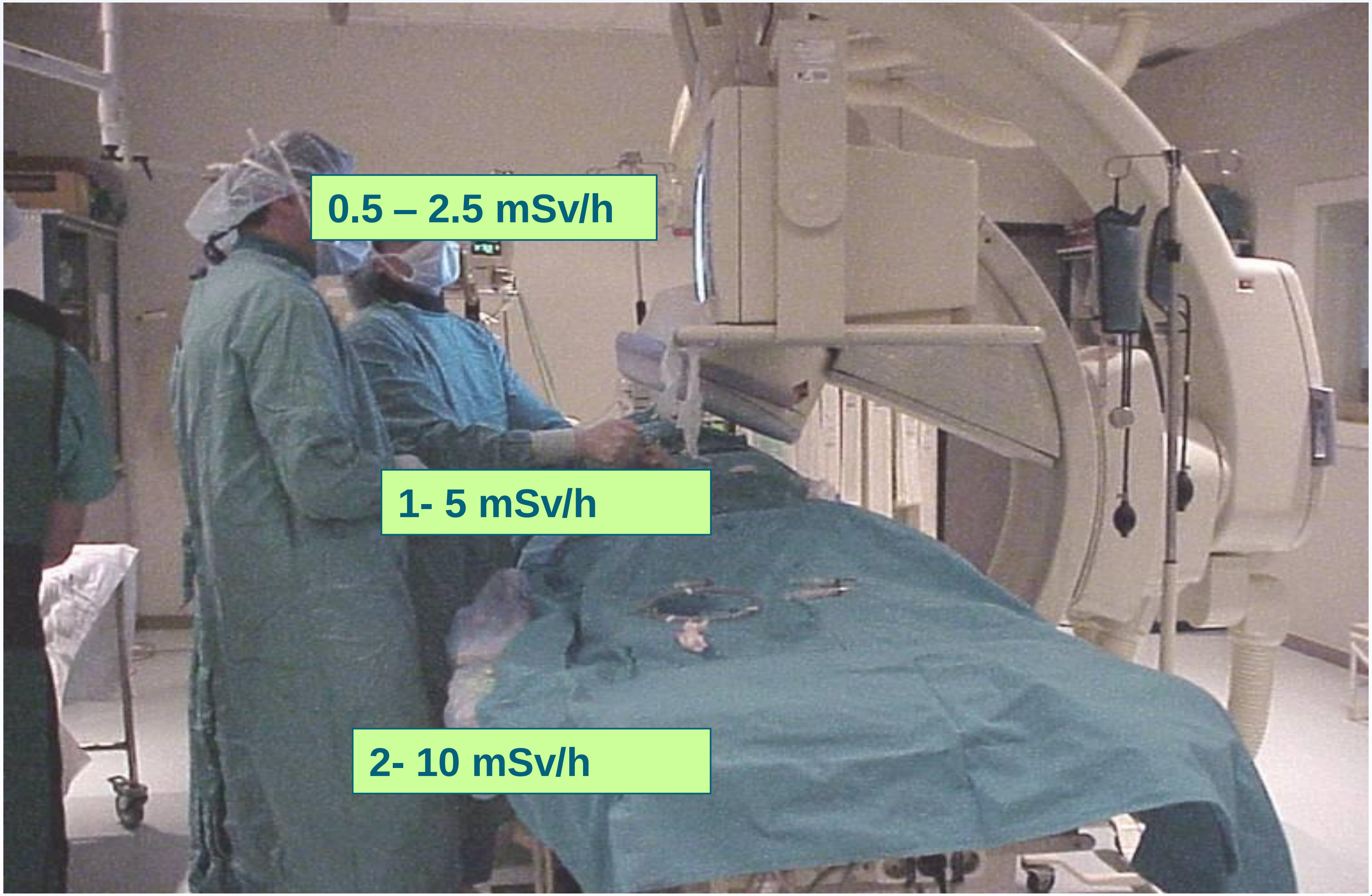


Doses to the lower leg and feet

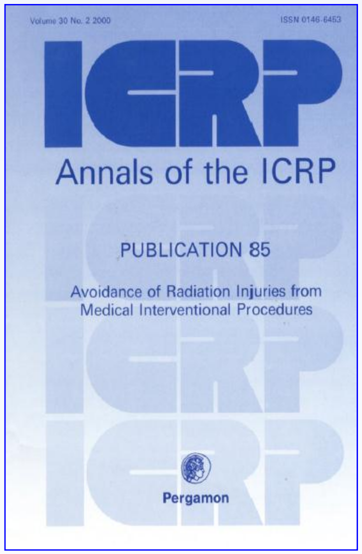
- Doses to the lower-legs from radiation scattered by the patient and couch can be higher than those to the hands If lead curtains suspended from the couch are not in place, [Whitby and Martin 2003]

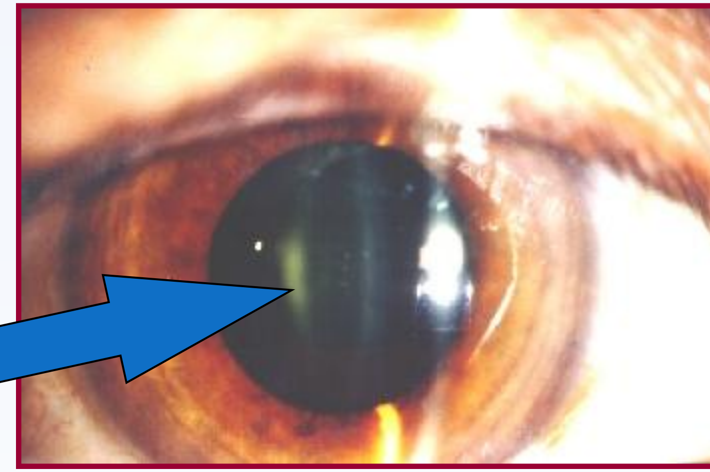


Eye doses



Publication ICRP No. 85 (2001): Avoiding radiation injuries from interventional procedures





Eye lense opacities of an interventionist after working in inadequate protection with high levels of radiation

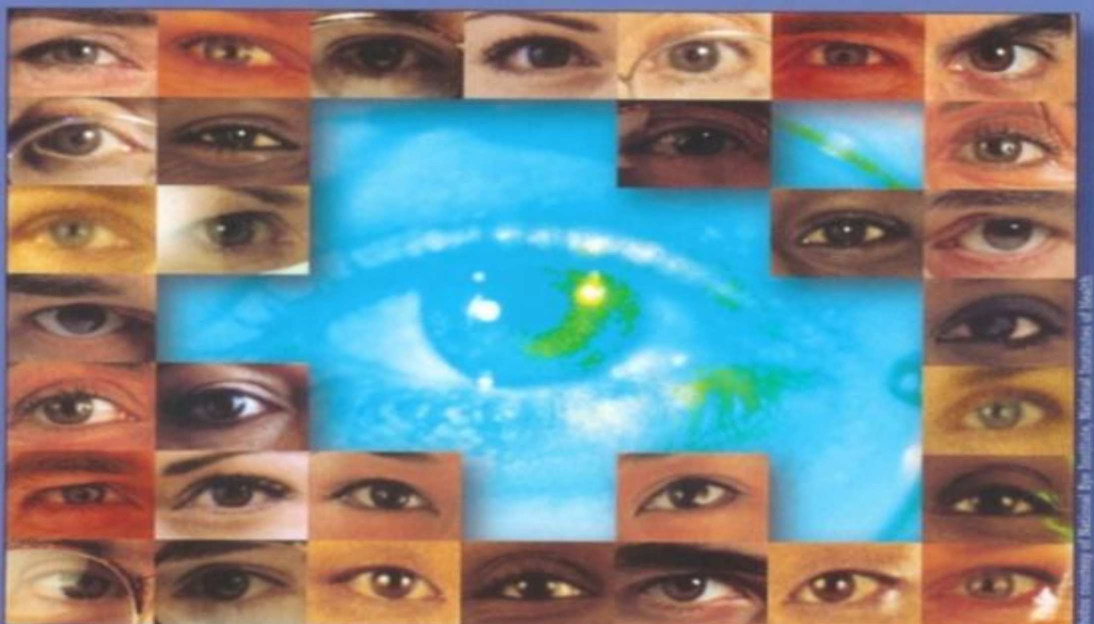
The British Journal of Radiology, *71* (1998), 728–733

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

JUNE 2004 • VOLUME 14, NUMBER 6

RSNA News



Interventional Radiology Carries Occupational Risk for Cataracts

Haskal study

Ziv J. Haskal, M.D.
Columbia University College of Physicians and Surgeons

- Dr. Haskal performed a study of cataracts and postcapsular opacities of 59 interventional radiologists participating in a conference New York in 2003.
- Nearly, half of the participating interventionalists had eye lens alterations

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Information for
Health Professionals
Member States
Patients

Member Area
- Member States Area
- Drafts Management Area

Home

IAEA Cataract study - List of Eye testing exercises conducted

No	Place (City, Country)	Dates	Regional/National organization	Links
1	Bogota, Colombia	25-26 Sept.2008	SOLACI[1]	RELID report Colombia [English], [Español]
2	Kuala Lumpur, Malaysia	17-19 April 2009	NAHM[2]	RELID report Malaysia
3	Montevideo, Uruguay	16-17 April 2009	SOLACI[1]	RELID report Uruguay [English], [Español]
4	Varna, Bulgaria	11-12 July 2009	NCCRP[3]	RELID report Bulgaria
5	Sofia, Bulgaria	13-15 July 2009	NCCRP[3]	RELID report Bulgaria

[1]SOLACI: Latin American Society on Interventional Cardiology

[2] NHAM: National Heart Association of Malaysia

[3]NCCRP: National Centre of Radiation Biology and Radiation Protection

The Haskal study triggered several campaigns supported by the IAEA on:

- Retrospective Evaluation of Lens Injuries and Dose (RELID)
- Interventionalists from 56 countries participated in succesive campaigns
- The results were similar to the Haskal study

RELID studies

Results of RELID studies

- RELID studies have shown that 50% of interventional cardiologists and 41% of nurses and radiology technologists, who voluntarily underwent ophthalmological controls at their congresses, have posterior subcapsular lens changes characteristic of ionizing radiation exposure, [Vano et al. 2013].
- Moreover, a recent RELID study specifically measured low-contrast vision in comparison to standard normal vision data (Vano et al, 2013) and confirmed some contrast loss

Summary

- Exposures
- Exposure monitoring and assessment
- Protective approaches

Assessment of effective dose approaches: single dosemeter under the apron

- The $H_p(10)$ reading of a single dosemeter under the apron underestimates effective dose, because it does not take account of the unshielded tissues (head, extremities, parts of the lungs and other tissues due to radiation entering through the arm holes)
- It requires, therefore a correction factor, to estimate the effective dose

Single dosemeter above the apron

- The $H_p(10)$ reading of a dosemeter above the apron (for example a collar dosemeter) overestimates effective dose, because it does not take account that tissues under the apron are shielded
- It requires, therefore a correction factor, to estimate the effective dose

Two-dosemeter approach

- Accuracy can be improved by combining the readings of two dosemeters (one on the collar and a second one under the apron)

Algorithm to combine the two-dosemeter readings to assess effective dose

- The two readings are combined with the following expresssion

$$E = \alpha H_{u} + \beta H_{na}$$

- To estimate effective dose
- Different pairs of (α,β) values have been obtained empirically for various beam geometries

A number of (α,β) pairs have been empirically developed with different projections or combination of projections

Algorithm comparisos (European CONRAD study)

- 11 sets of published (α,β) values were compared with Monte Carlo simulations for different geometries and with phantom measurement (Järvinen, 2008)
- Criteria for the appropriateness of the sets of values : no **under**estimation, least **over**estimation and closeness to effective dose

The three sets of values, which best met the criteria were:

	With thyroid shielding			Without thyroid shielding	
Parameters	α	β		α	β
Swiss Ordinance [2008]	1	0.05		1	0.1
McEwan [2000]				0.71	0.05
Von Boetticher et al [2010]	0.79	0.051		0.84	0.100

Conclusion of the study: none of the published algorithms is optimal for all possible radiation geometries and, therefore, compromises have to be taken for their application

Pragmatic approaches

- The lack of international consensus on the α and β values renders comparisons of effective doses meaningless
- The reliability of the staff wearing two dosimeters correctly and consistently is questionable
- For these reasons a number of authors have suggested a more pragmatic approach of using a single dosemeter above on the collar and a conversion factor 0.1 to estimate effective dose **(E=0.1H_a)** (Kuipers, 2008, Martin, 2012, NCRP 168)
- For specific cases of high dose readings, an investigation of the exposure conditions and the two-dosemeter approach may be warranted

Assessment of doses to the eye lenses

- Behrens et al. investigated the adequacy of the operational quantities at the depths, 0.07, 3 and 10 mm for assessment of eye lens equivalent dose from x-ray fields (Behrens 2012b) and concluded that both quantities $H_p(0.07)$ and $H_p(3)$ are adequate for photon exposure when the dosimeters are calibrated on a slab phantom for simulating backscatter. Similar results were reported by the ORAMED Project (Vanhavere et al).

Practical approaches for controlling exposure of eye lenses

- The collar dosemeter, using $H_p(0.07)$ instead of $H_p(10)$, may provide a reasonable assessment of eye lenses under normal circumstances
- It is only an indicator of eye dose, rather than an accurate measurement and it requires a dose reduction factor for the goggles (Clerinx et al 2008, Magee and Martin 2009)
- In cases that the reading is relatively high,
  - investigation and
  - follow-up using an additional dosemeter to detect the doses actually received by the eye lens

Trend to more specific dosimetry

Assessment of doses to the hands

- For the majority of procedures the outer side of the hand is closer to the primary beam thus receiving the higher dose, so dosimeters should be worn either on the little finger or the outer side of the wrist closest to the beam [Whitby and Martin 2005, Vanhavere et al 2012]

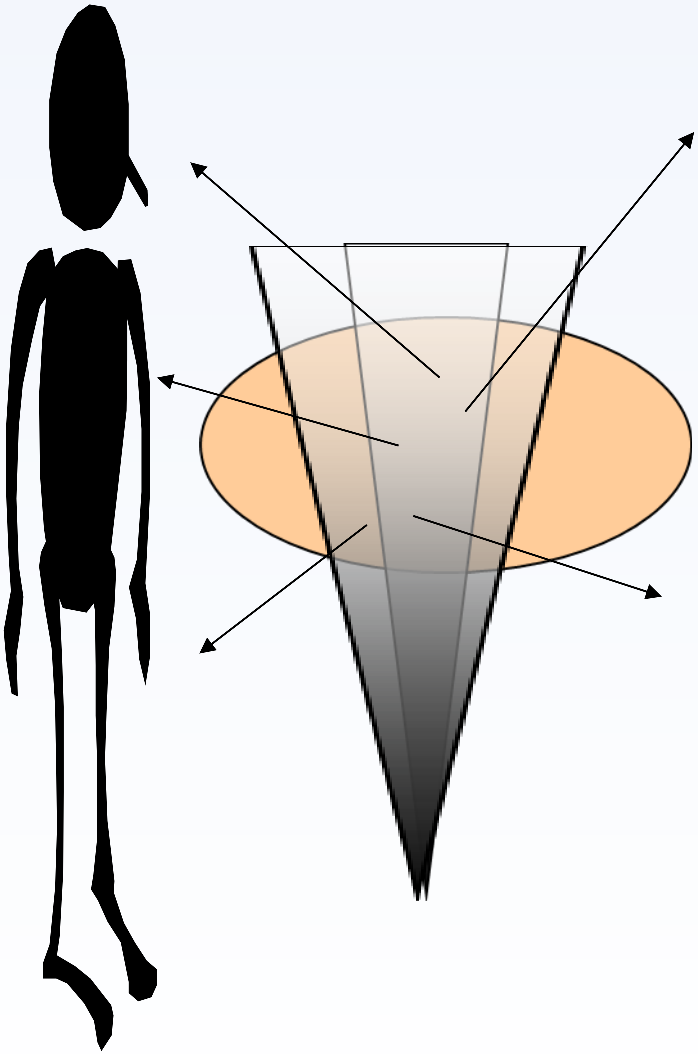
Use of active dosemeters, especially effective for

- Educational and awareness purposes
- Implementing optimization actions and showing their impact

Summary

- Exposures
- Exposure monitoring and assessment
- Protective approaches

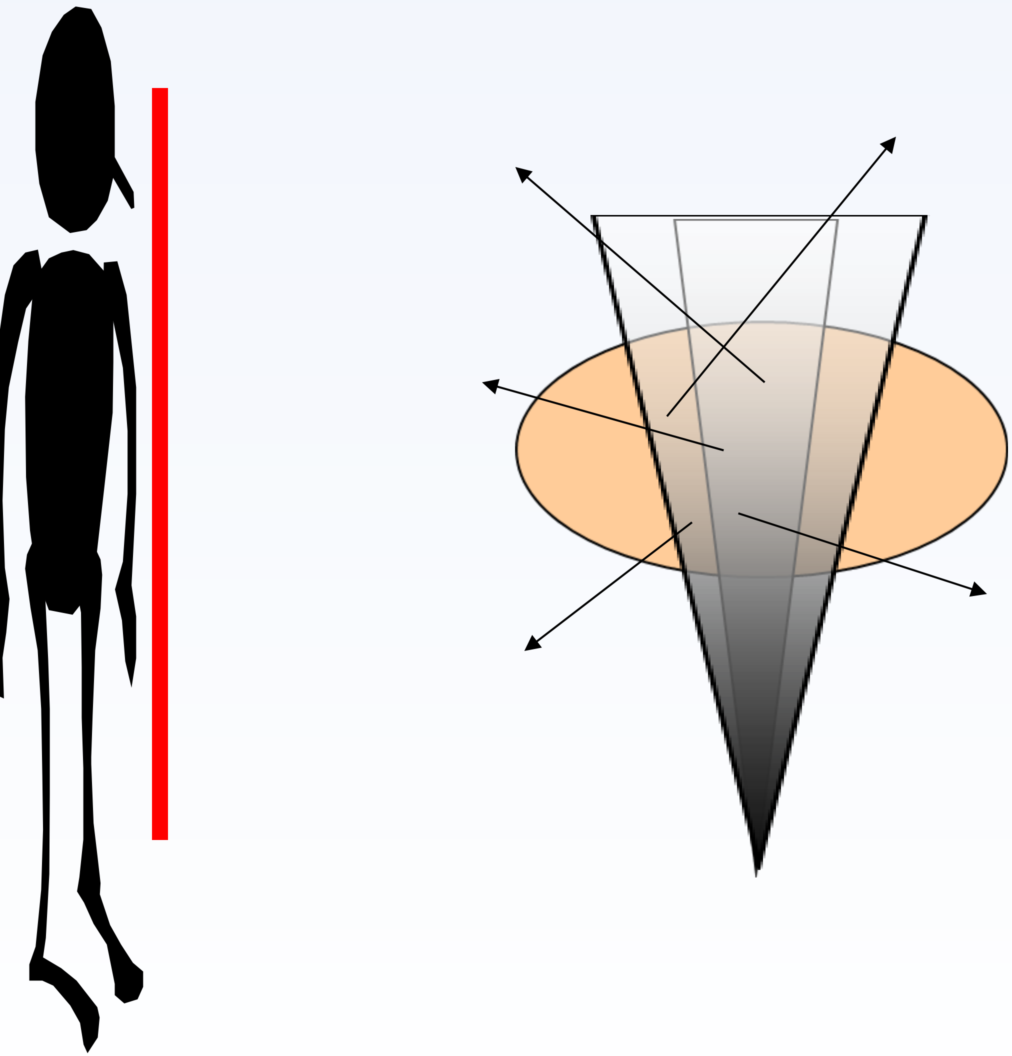
Relationship of patient and occupational exposure



- The exposure to the staff is proportional to
  - "beam-on" time
  - beam intensity and
  - irradiated volume (mass)
- Approaches to reduce patient exposure also reduce staff exposure

Occupational exposure

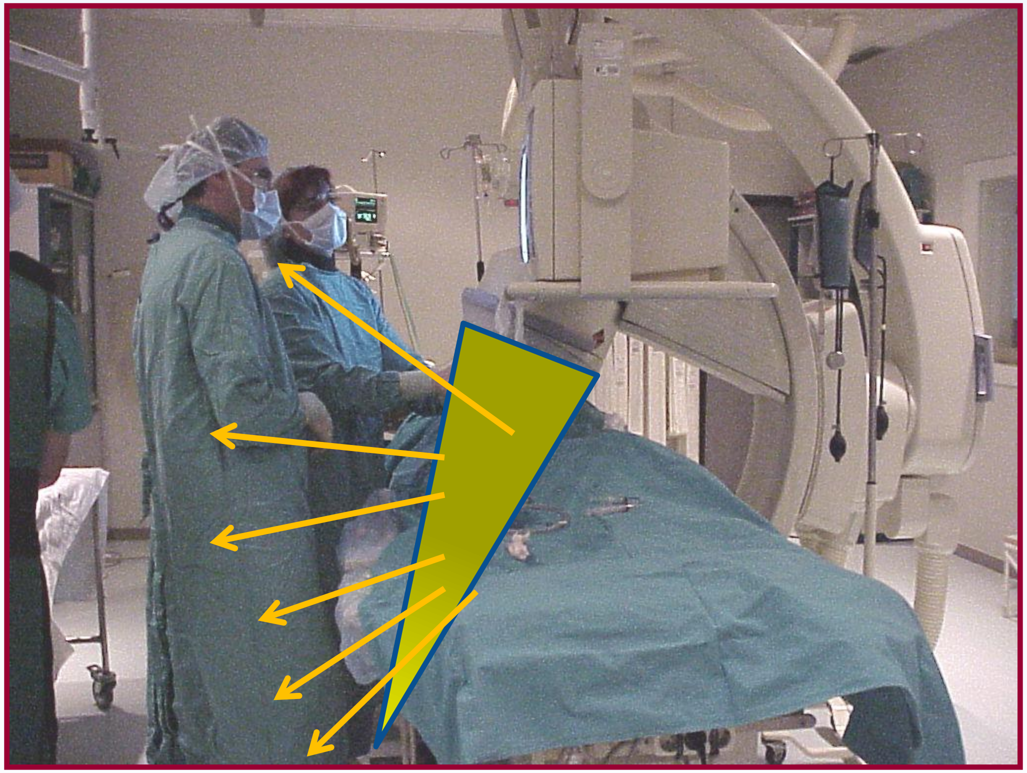
distance and shielding



- The opposite in not true: it is possible to reduce staff exposure without reduction of the patient exposure

Examples of dose reduction to patient and staff at the same time

- Reducing unnecessary fluoroscopy time
- Using pulsed fluoroscopy with a moderate-low pulse frequency
- Acquiring only the number of cine series and frames per series that are necessary
- Using “last-image hold” and “image loops”

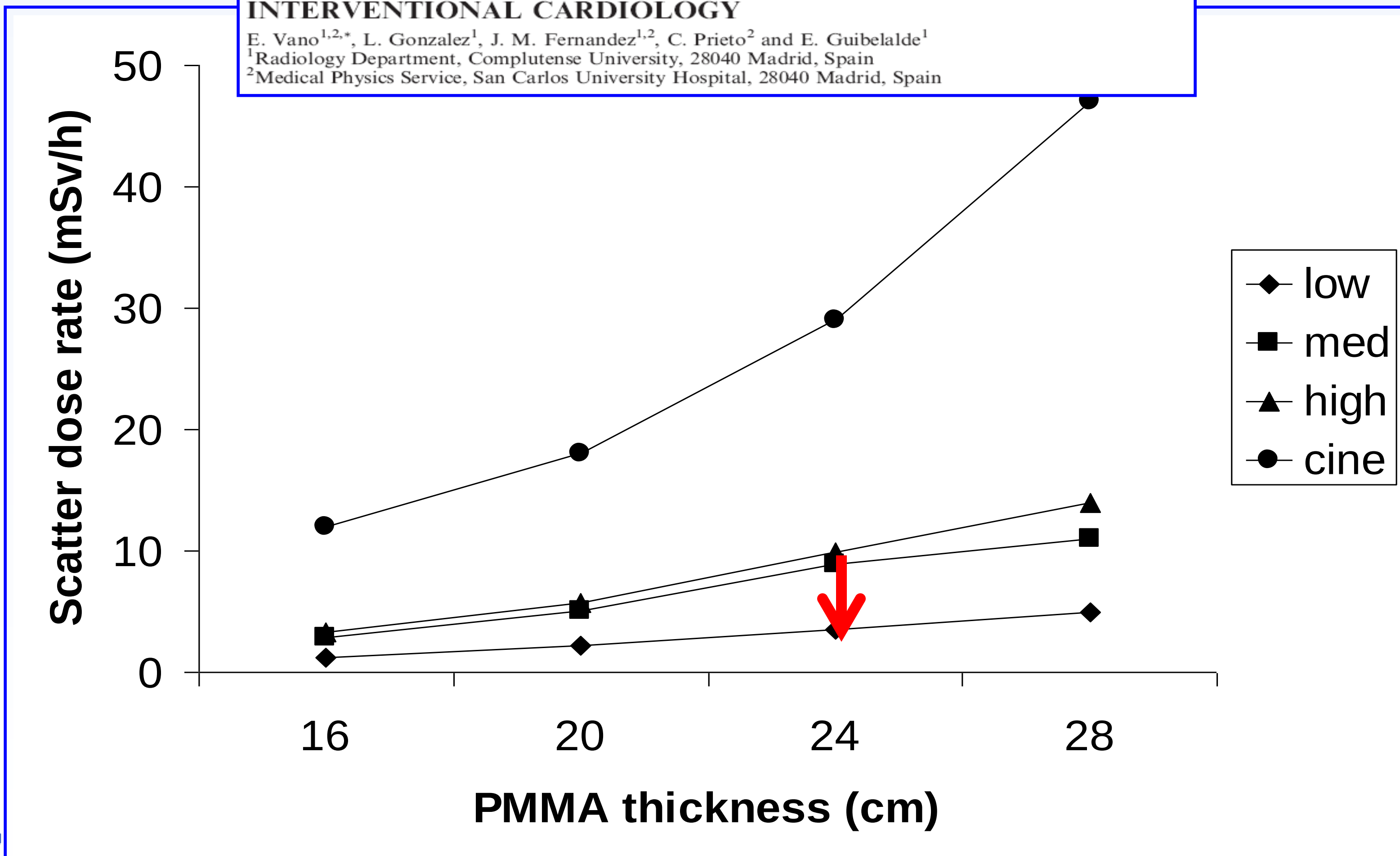


Example: reducing the use of higher dose rate modes (1)

Radiation Protection Dosimetry (2006), 1 of 6
doi:10.1093/rpd/nci369

INFLUENCE OF PATIENT THICKNESS AND OPERATION MODES ON OCCUPATIONAL AND PATIENT RADIATION DOSES IN INTERVENTIONAL CARDIOLOGY

E. Vano[1,2,*], L. Gonzalez[1], J. M. Fernandez[1,2], C. Prieto[2] and E. Guibelalde[1]
[1]Radiology Department, Complutense University, 28040 Madrid, Spain
[2]Medical Physics Service, San Carlos University Hospital, 28040 Madrid, Spain



Reducing the use of higher dose rate modes (2)

Radiation Protection Dosimetry (2006), 1 of 6
doi:10.1093/rpd/nci369

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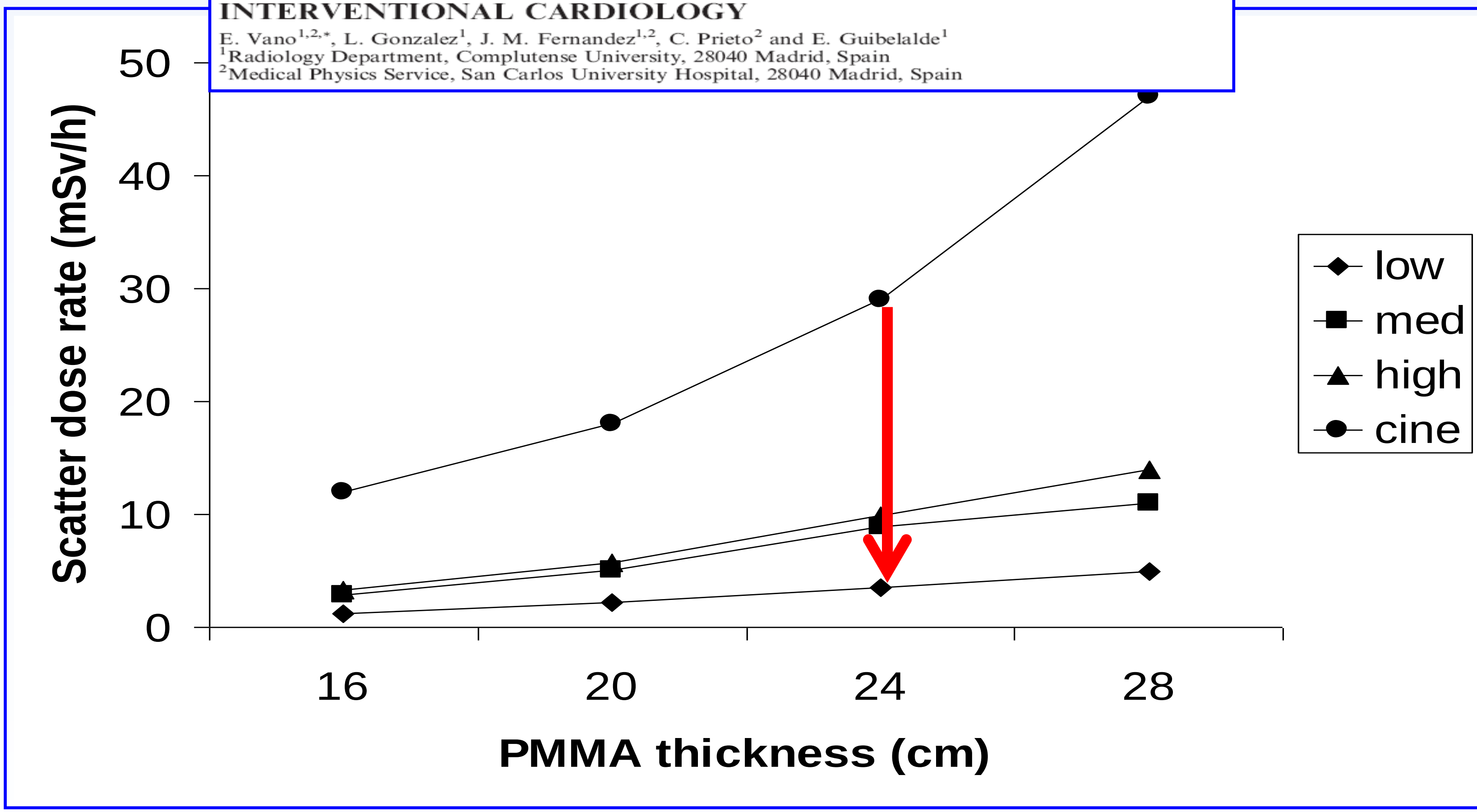

Thickness of the patient crossed by the beam

Radiation Protection Dosimetry (2006), 1 of
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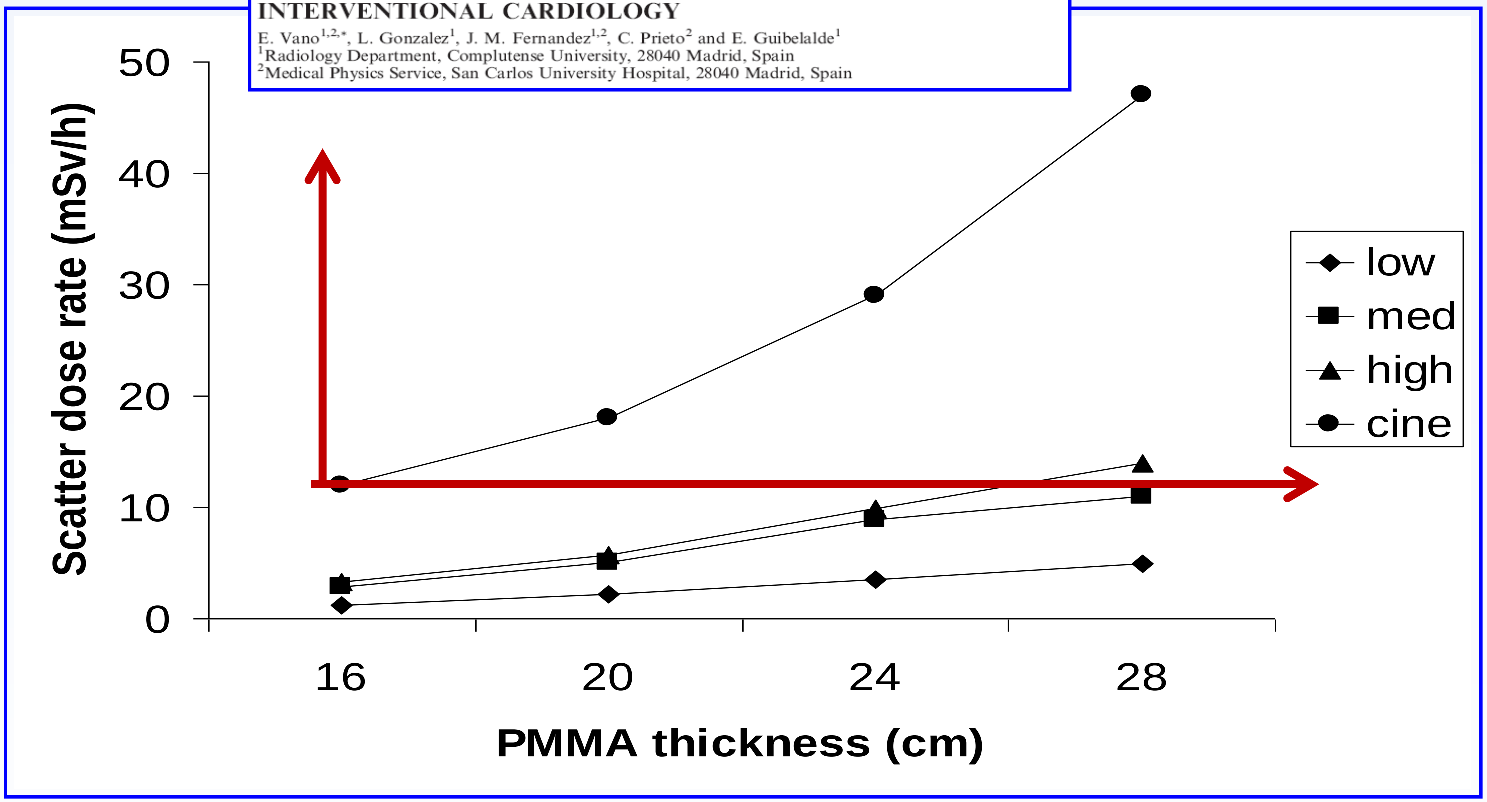
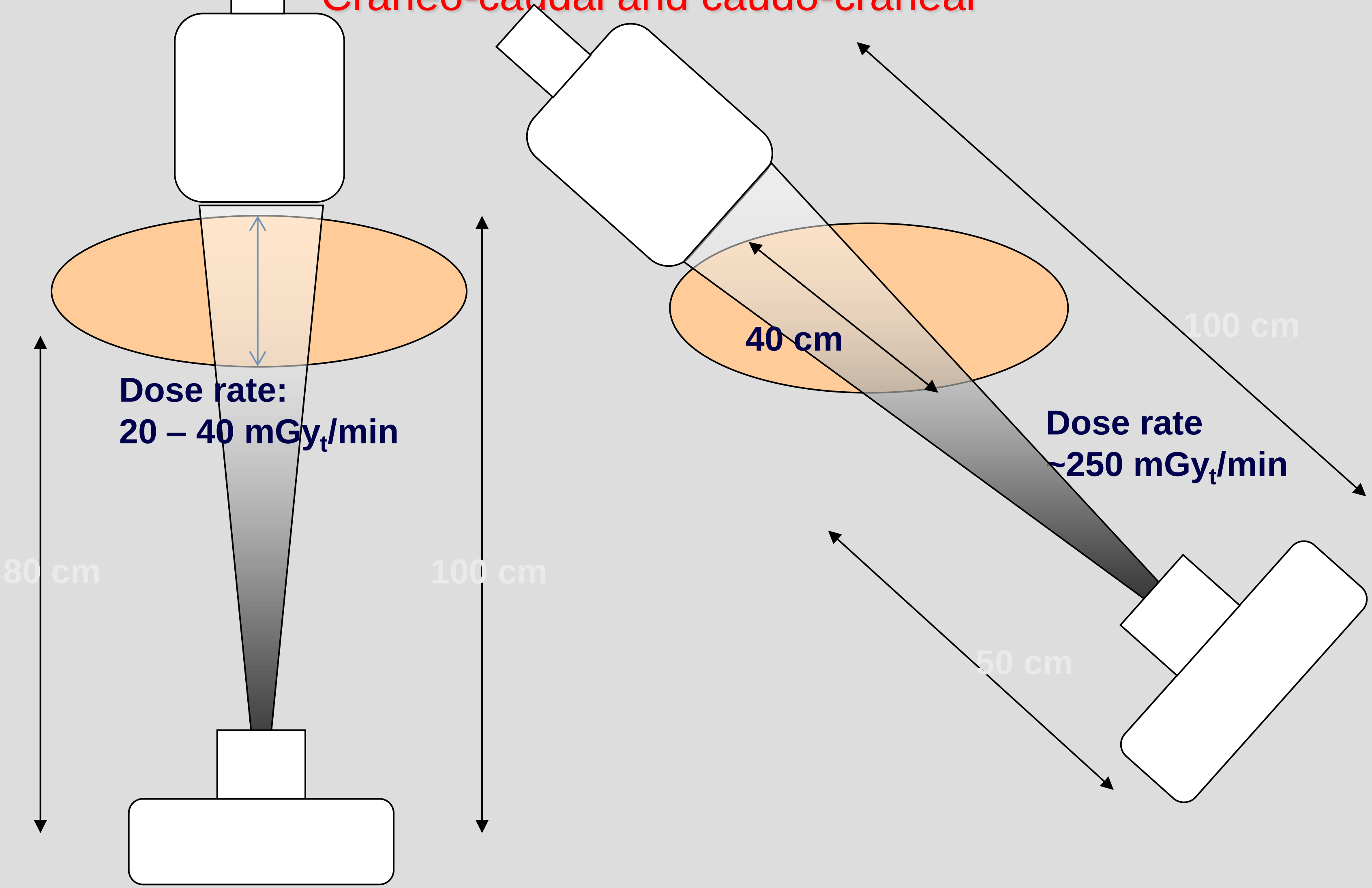


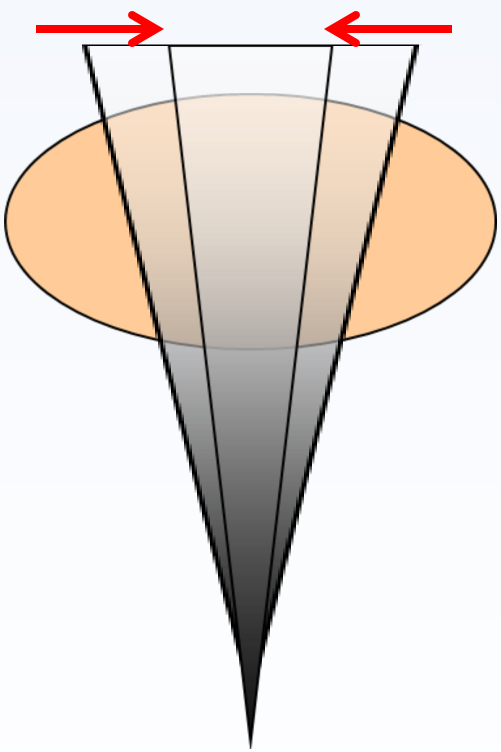
Example: cautiously using steep oblique projection

Craneo-caudal and caudo-craneal



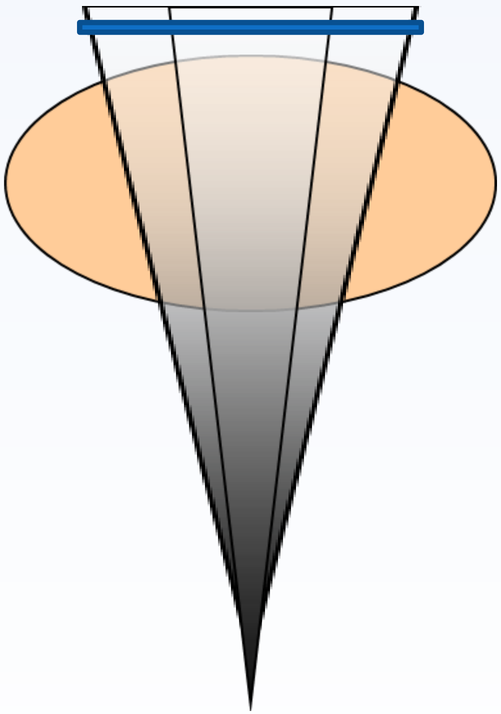
Further examples of dose reduction to the patient, which also reduces staff doses

- Narrowing the collimation to the required field of view (FOV): it reduces the irradiated volume of the patient and reduces dose to the staff. In addition, it reduces the potential stray of the hands into the beam



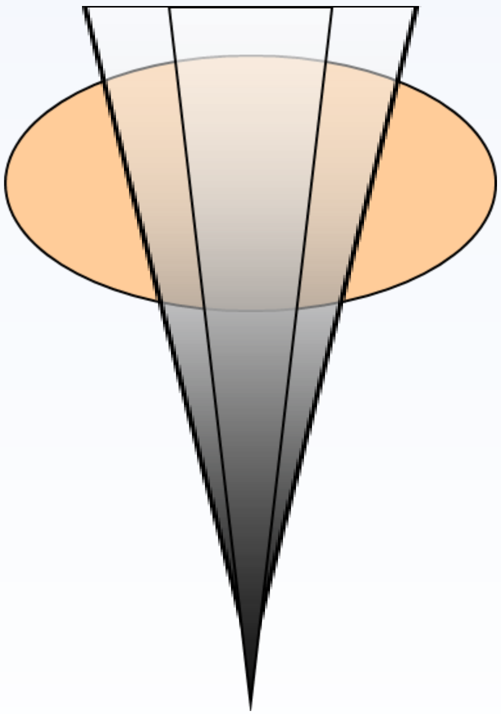
Further examples of dose reduction to the patient, which also reduces staff doses

- In interventions of small children, removal of the antiscatter grid reduces the patient dose and also the dose to the staff



Further examples of dose reduction to the patient, which also reduces staff doses

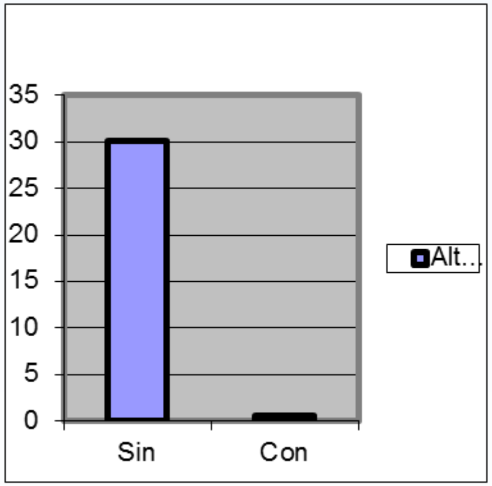
- In interventions of small children, removal of the antiscatter grid reduces the patient dose and also the dose to the staff (dose reduction factor 2-3)



Protective equipment

Ceiling suspended screens

- Ceiling-suspended lead acrylic-lead shields should be a requirement for interventional installations (attenuation factor of around 20), and if practice it can reduce doses to the head and neck by factors of 2-10 or higher.
- However, actual dose reduction depends on the regular use by interventionalists and how effectively they are positioned.



Attenuation factor ≈20

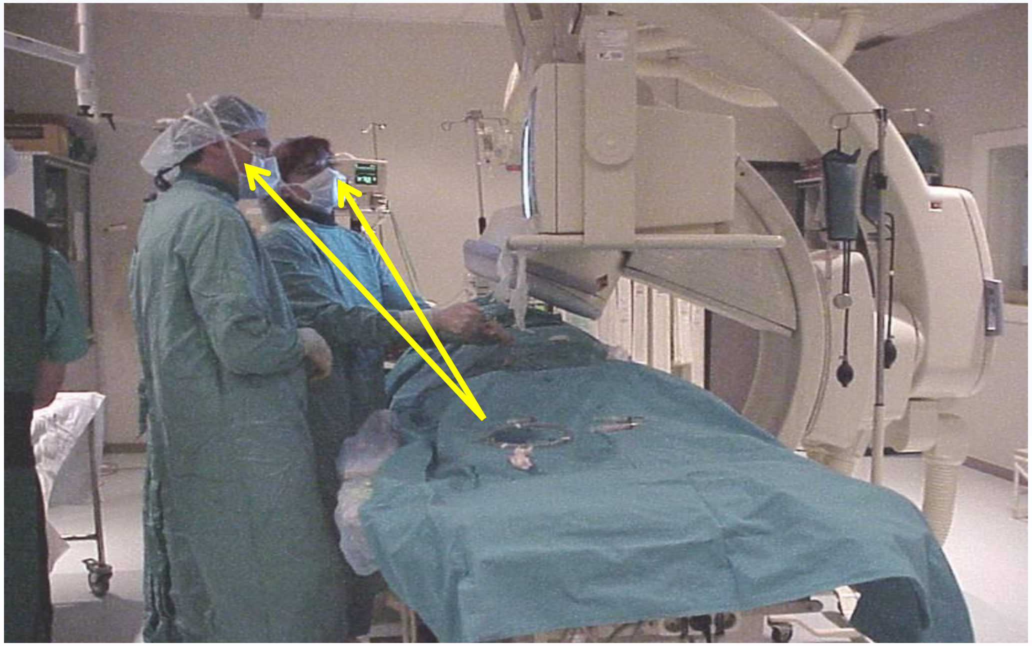
Protection of the legs and feet

- Rubber-lead suspended from the patient table reduce doses to the legs by factors of 10 to 20 if correctly positioned throughout a procedure [Martin 2009],
- But factors between 2 and 7 are typical in practice [Vanhavere et al 2012].

Making use of protective screens and curtains

Protective goggles

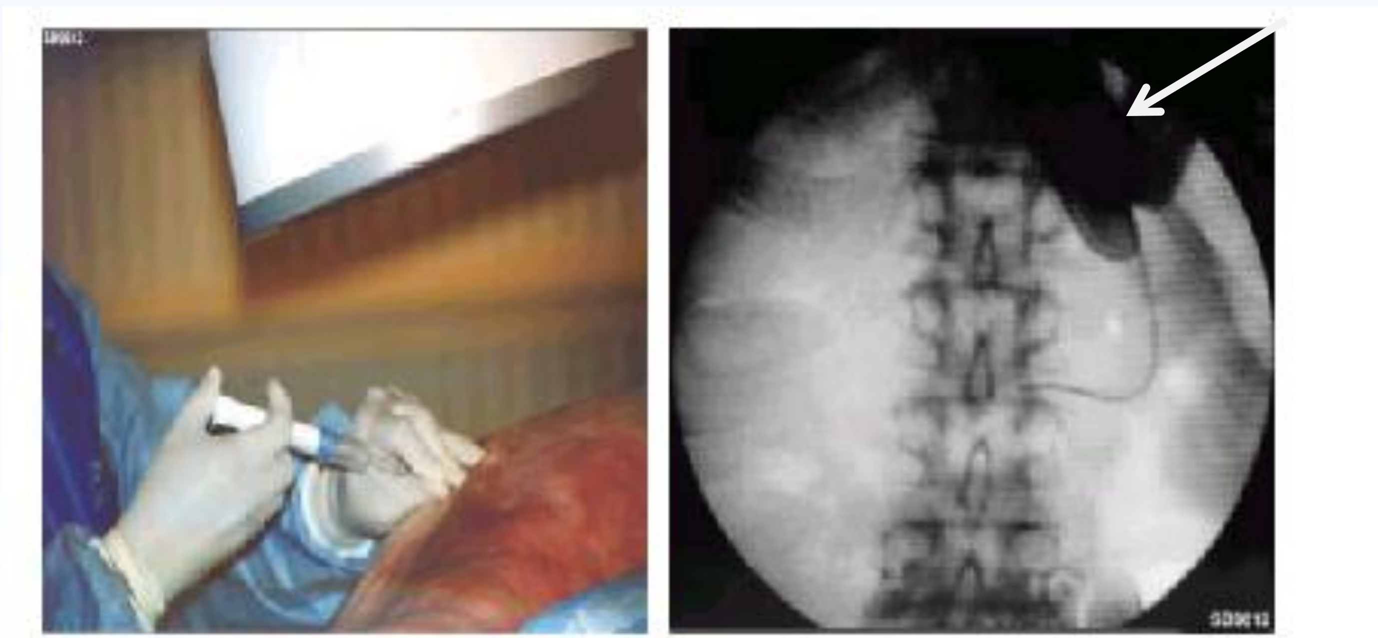
- A "close fit" to the facial contours, as the glasses must also provide protection against radiation scattered from the face of the staff, i.e., from below and from the side



Radiation Protection of Hands

Best way to minimize dose to fingers and hand:

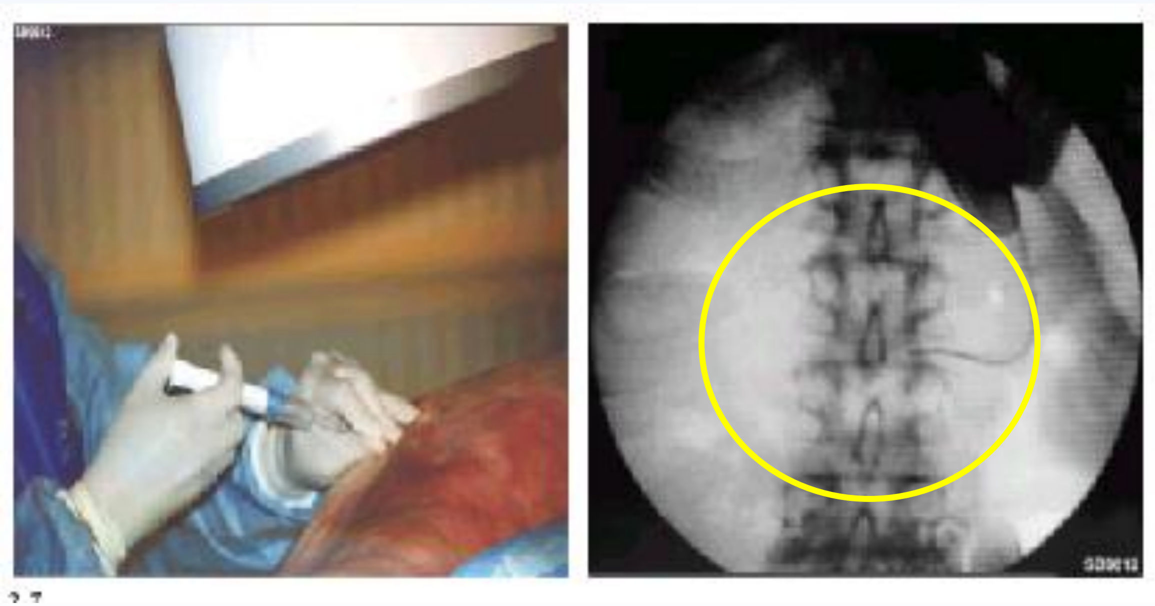
Keeping fingers out of the beam

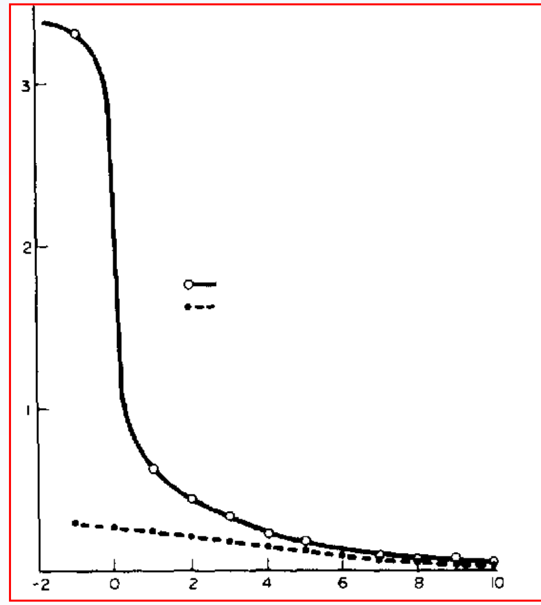


INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

Hand dose reduction

- Collimation of the beam (field of view) to avoid the hands into the beam





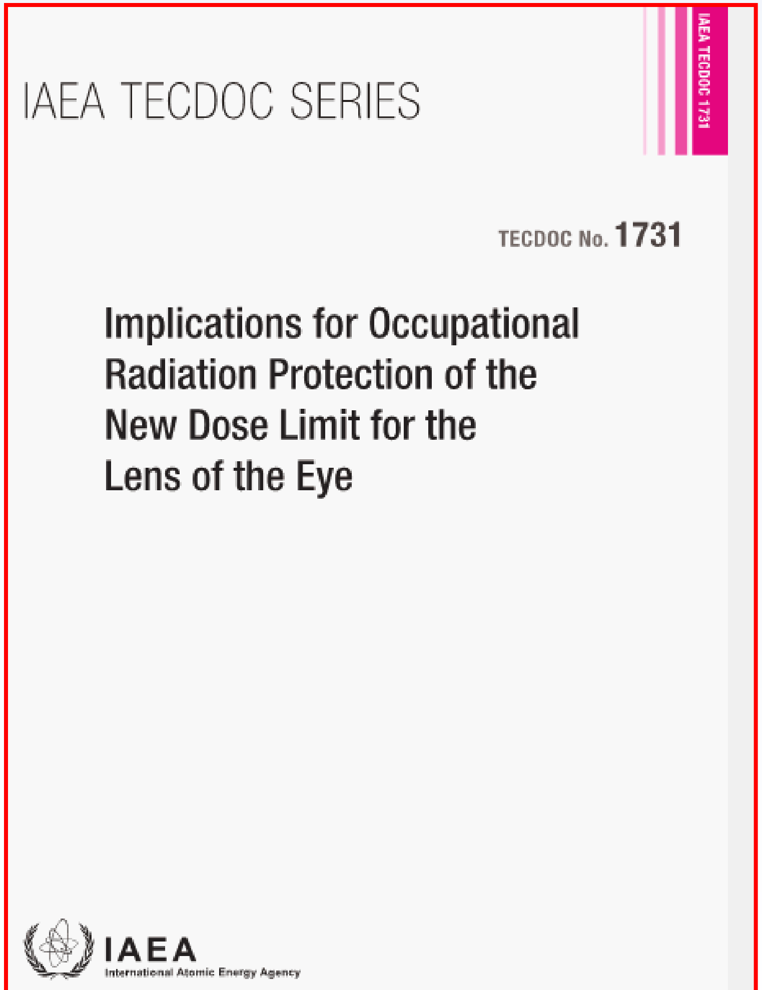
Hand protection

- Protective drapes and pads can offer good protection for the hands and have been shown to achieve a 29-fold reduction in the dose to the hands in one study [King et al 2002].

Personal protective equipment

Thyroid protectors, emphasis on young workers

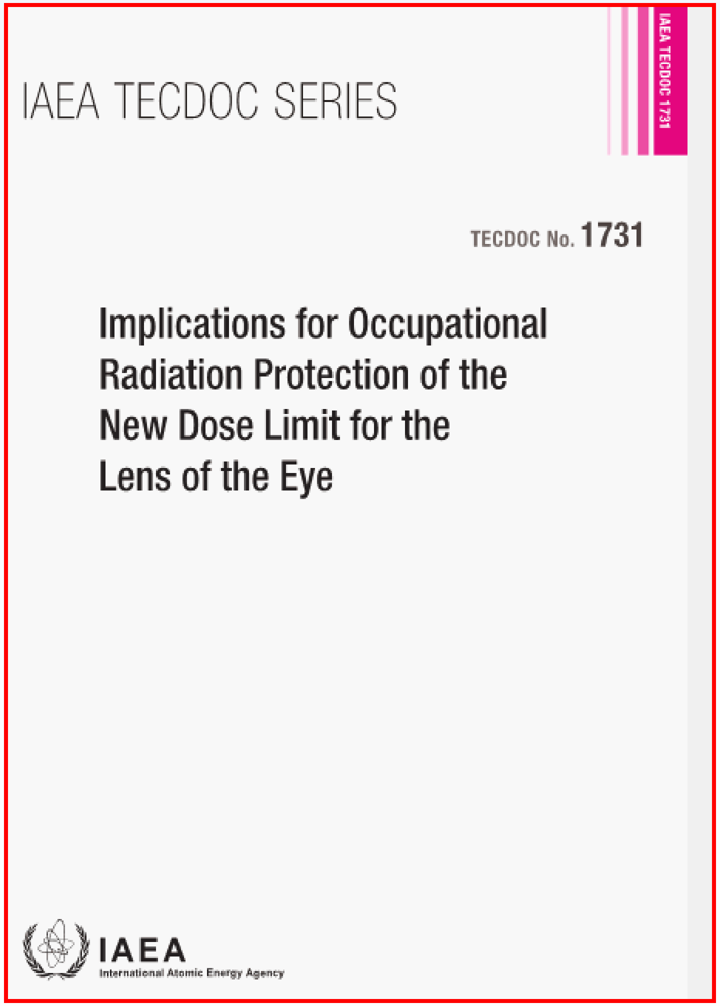
Conclusions IAEA TECDOC 1731



- Workers who have not received annual doses to the lens of the eye **of more than 20 mSv** on average over their working lives, need not be subject to any additional medical examination beyond what is required by the above general principles of occupational health

Health surveillance (TECDOC 1731)

- Workers who have already received accumulated doses to the lens of the eye of **more 0.5 Gy** or …may need to be subject **to regular visual tests**
- This is related to the ability of the workers to carry out the intended tasks (e.g. in interventional radiology) and should not be regarded as a radiation protection measure as such


IAEA TECDOC SERIES

IAEA TECDOC 1731

TECDOC No. 1731

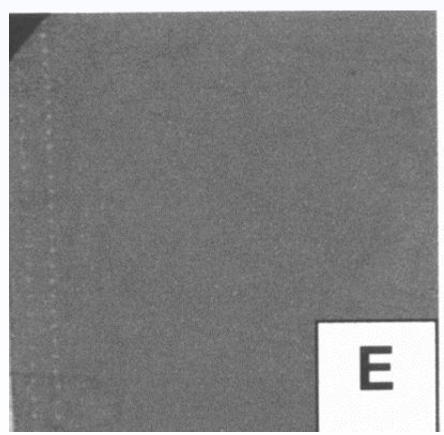
Implications for Occupational Radiation Protection of the New Dose Limit for the Lens of the Eye

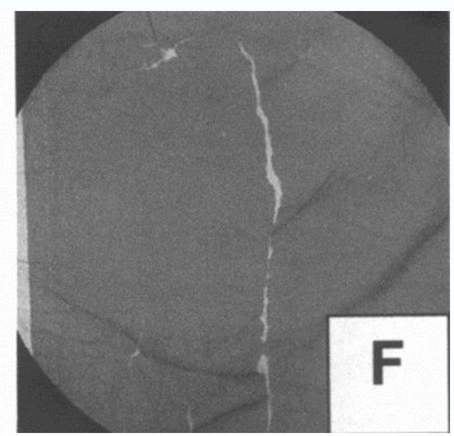
IAEA
International Atomic Energy Agency

Issues of maintenance of protective devices

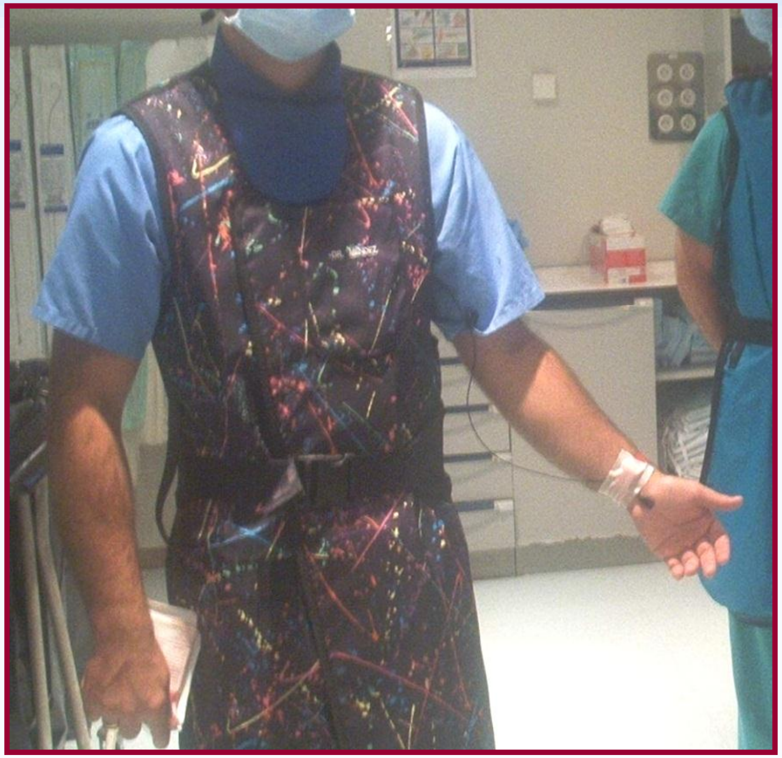
Personal protective equipment

Hang aprons! Do not fold them!





From IAEA training material



Before

After (incorrect) cleaning
US$ 1000 lost !!!

Expensive lead apron sent to the cleaning service of the hospital without the appropriate instructions

“Take-home” points

Actions to reduce patient exposure that will reduce occupational exposure as well

- Reducing beam-on time
  - Reduce unnecessary fluoroscopy time
  - Use pulsed fluoroscopy with a moderate-low pulse frequency
  - Acquire only the number of cine series and frames per series that are necessary
  - Use “last-image hold” and “image loops”

Actions to reduce patient exposure that will reduce occupational exposure as well

- Reducing beam intensity
  - Use low-dose rate modes, replace cine with recorded fluoroscopy, when possible
  - Cautious use of steep beam angulations
- Reducing irradiated volume (mass) of the patient
  - Collimate the beam to the area of interest
  - Keep hands outside the primary beam by adjusting the beam accordingly

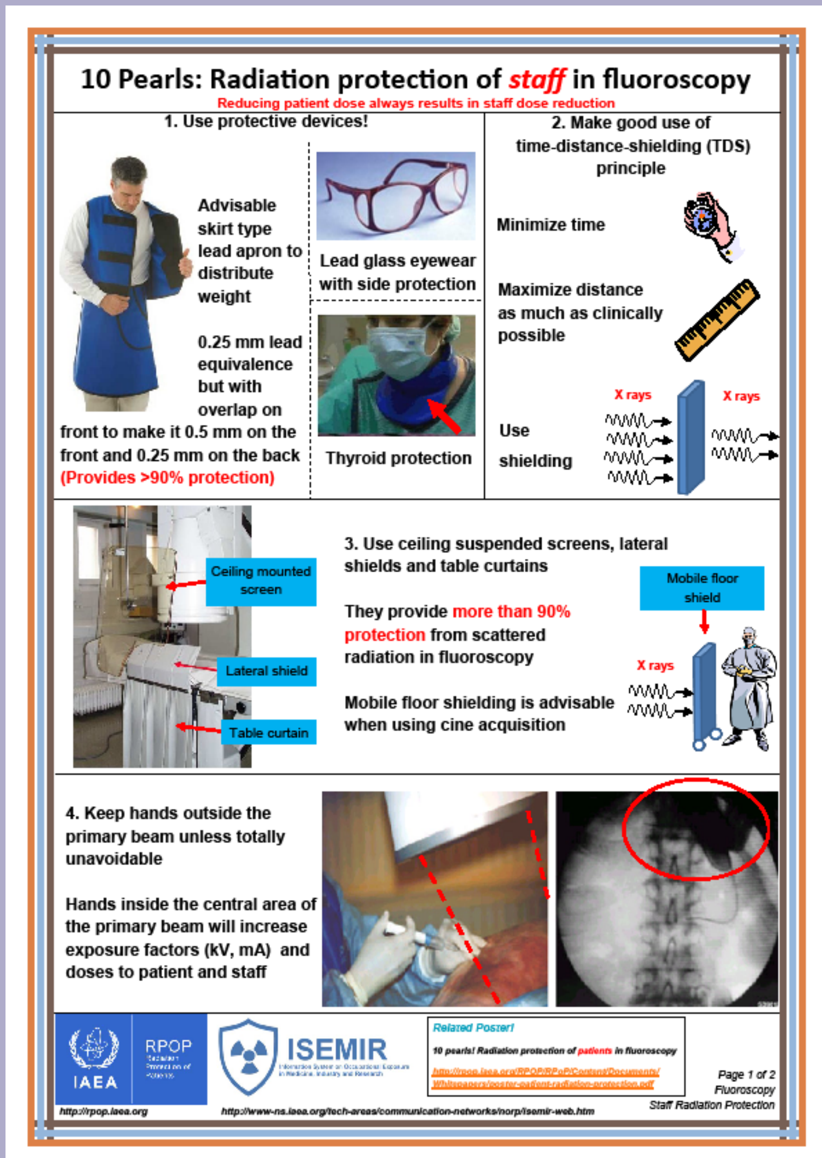
Protection of the staff only

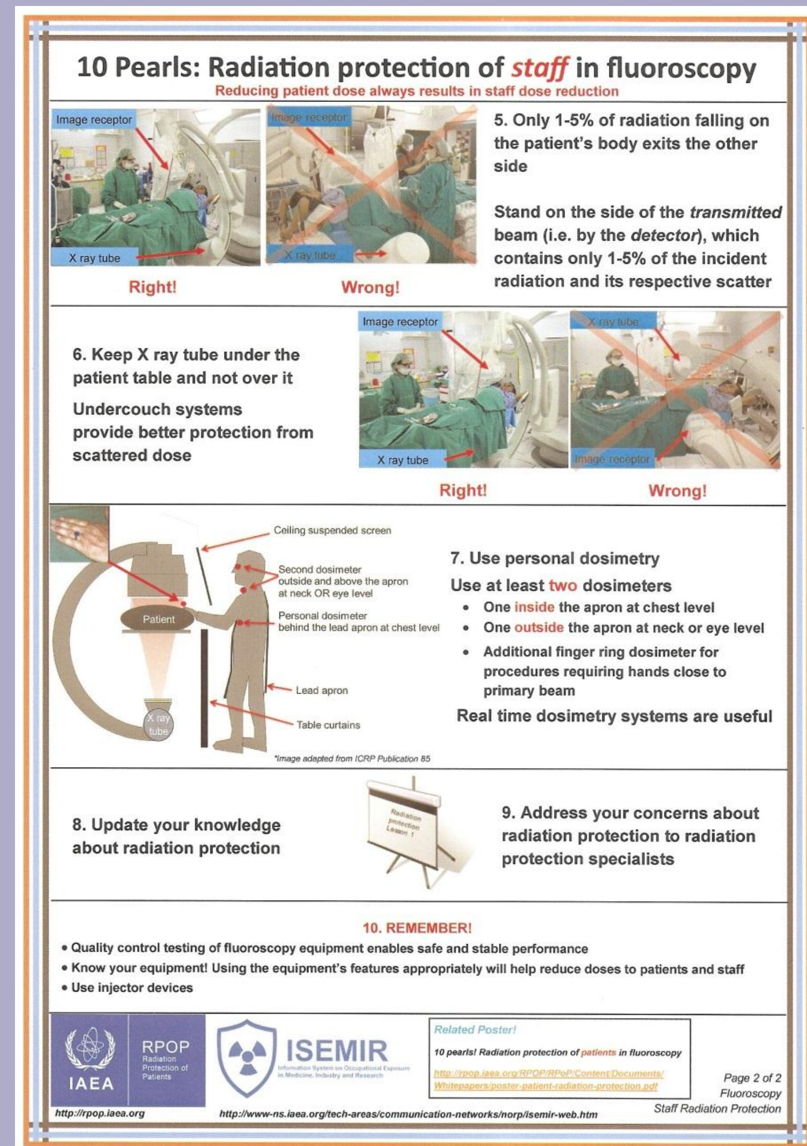
- Using shielding
  - Use protective devices, apron, ceiling suspended screens, goggles with side protection, thyroid protection, table top mounted curtains
  - Keep x-ray tube under the patient table, not over it. Stay on the side of the image system
- Increasing distance:
  - Step back for “cine runs” when possible

Last but not least

- Use individual dosimetry and discuss significant readings with the radiation protection officer
- Update your knowledge

10 points to remember





Thank you for your attention