Welcome to the Radiation Safety in Fluoroscopy Webinar

THE WEBINAR WILL START SHORTLY

Radiation Safety Institute of Canada
Institut de radioprotection du Canada

Good Science in Plain Language®

2017

Webinar Functionality

- Audience is in silent mode by default
  - Only the presenter's audio will be transmitted
- Webcam will be off during actual presentation
- Audio: use computer or telephone (call in)
  - Computer seems to give the best sound quality
- Use the "Chat" feature to enter comments
- Use the "Questions" feature to ask questions
  - Will be answered at the end of the webinar

Webinar Functionality

- A copy of the slides is available as a handout in the “handouts” section, which you can download at any time during the webinar
- After the webinar, when the recording becomes available and has been added to our website, a link to the webinar will be sent to participants

Information about Attendees

- We would like some information about you and your fluoroscopy experience
- We will use the polling feature of the webinar system to ask you (all answers are confidential):
  - What is your occupation?
  - Do you wear eye protection during fluoroscopy procedures?
  - What is the longest fluoro time procedure you have been involved with?

Radiation Safety in Fluoroscopy

Curtis Caldwell, Ph.D., MCCPM
Chief Scientist
Radiation Safety Institute of Canada

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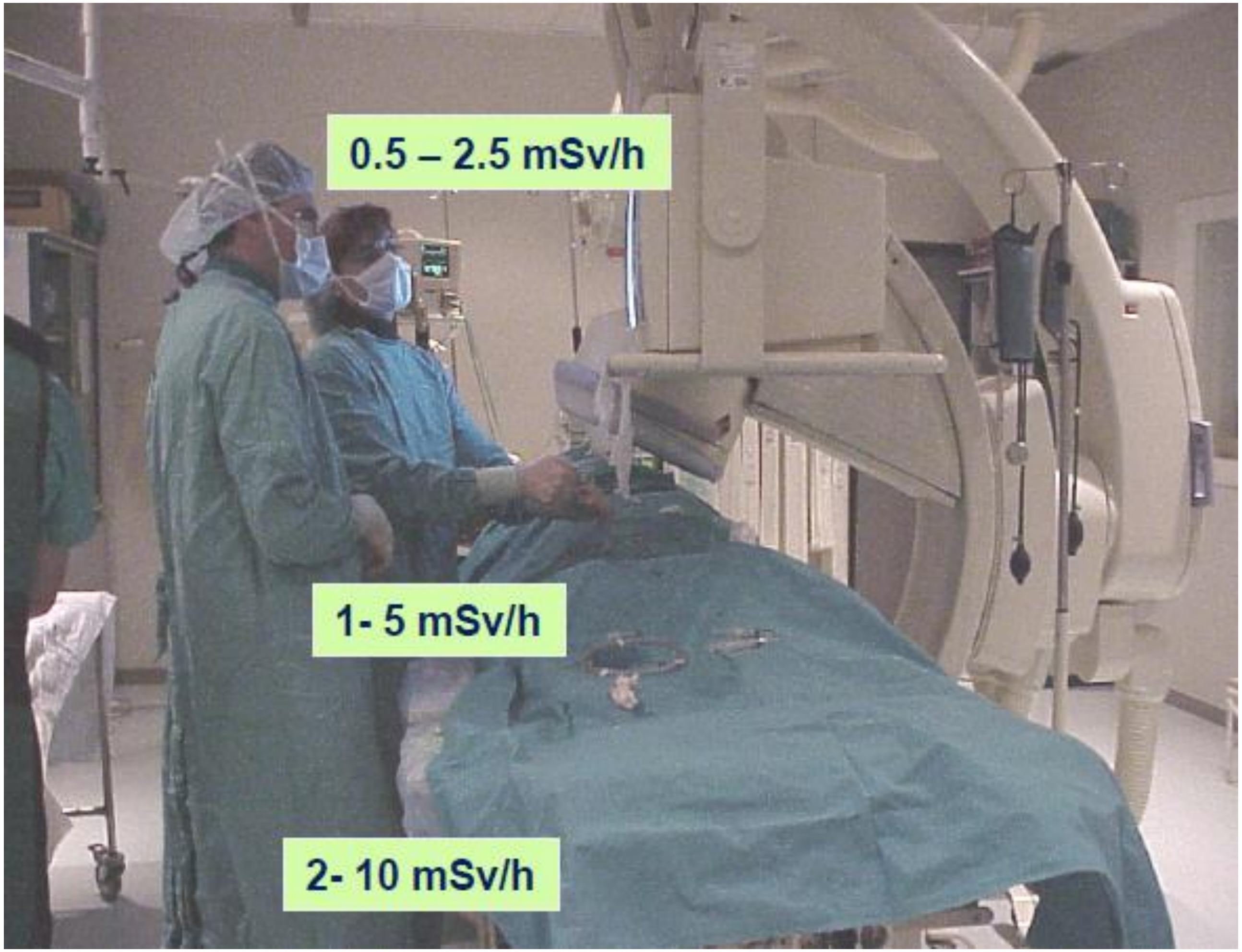
Radiation Safety in Fluoroscopy

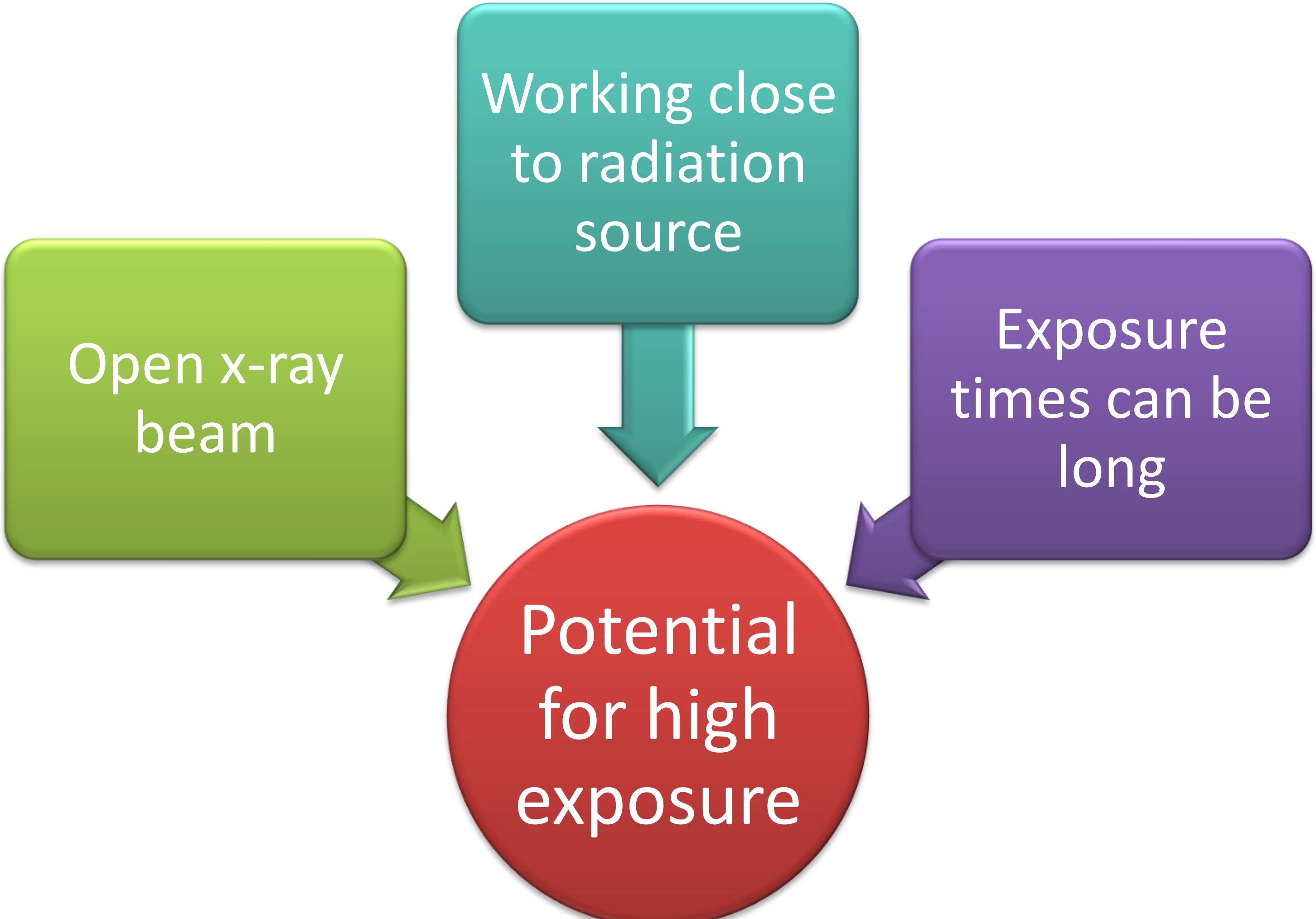
- Review of risk due to exposure to ionizing radiation such as x-rays
- What adverse effects are we trying to prevent?
- Equipment used in fluoroscopy
- Managing dose to the patient
- Reducing staff dose
- Summary

Fluoroscopy suites may be high radiation exposure work areas



Source: ICTP/IAEA Training Course on Radiation Protection of Patients (R Padovani)

Occupational Risk: Fluoroscopy



Medical Radiation Exposure

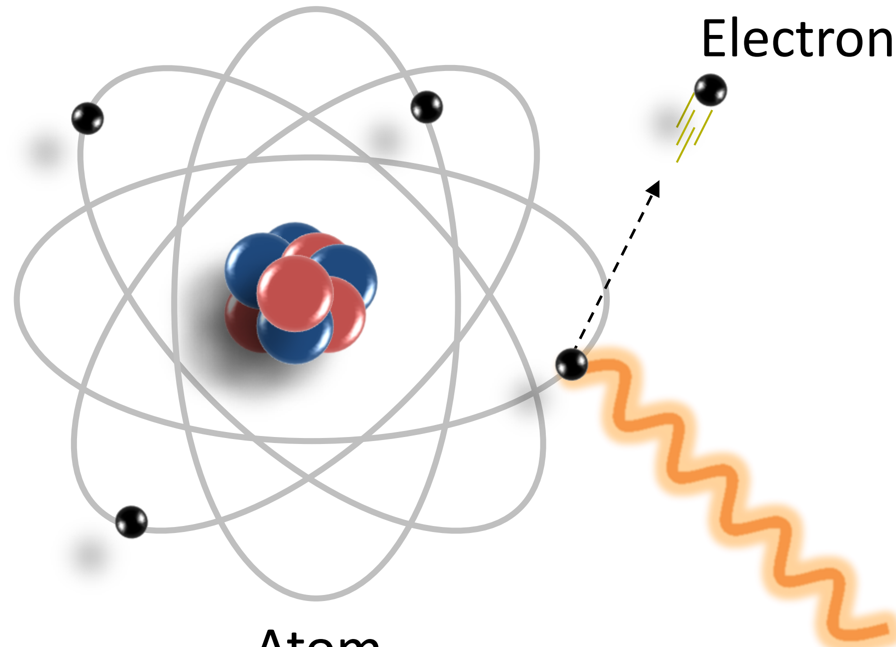
Crucial to be aware of:

- Worker Dose
- Patient Dose

Ionizing Radiation

When radiation such as an x-ray strikes matter, it interacts with the atoms of the matter.

Radiation with enough energy can knock **electrons** out of orbit from the atoms it strikes.



Interaction with the Body

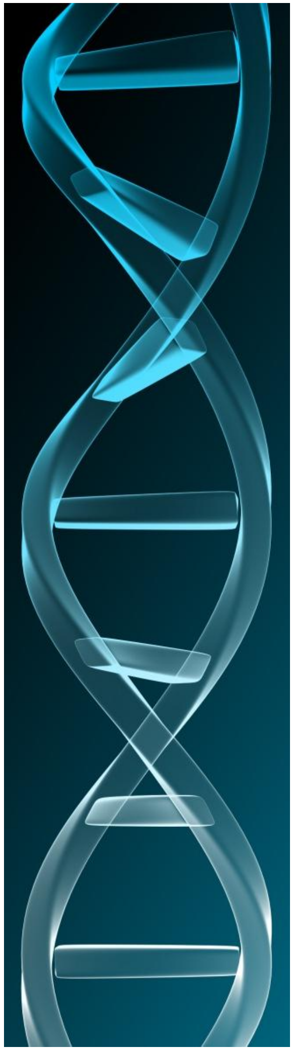
When radiation strikes living tissue, there are a number of possible outcomes:

- No damage caused
- Damage to cells that is repaired
- Damage to cells that leads to cell death
- Damage to cell chromosomes that is incorrectly repaired (“mutated”)

No harm (no damage caused; damage to cells that is repaired)

Deterministic effects (damage to cells that leads to cell death)

Risk of cancer (damage to cell chromosomes that is incorrectly repaired)



Radiation Concern: Cancer

Radiation exposure increases the **probability** of developing cancer.

→

Probability increases with dose received, assumed to be linear without threshold (LNT)

Effect is similar to smoking increasing the risk of lung cancer

Cancer Risk from Radiation

- The risk of developing a fatal cancer as a result of exposure to radiation is approximately **4% per 1000 mSv.**
  - Consider 1000 people who worked for 50 years and each received 20 mSv per year.
  - Their total lifetime radiation dose is 1000 mSv (1 Sv).
  - This population will have an extra 4% chance of developing a fatal cancer (baseline risk is 25%)
    - 290 cancers expected instead of 250.

Radiation Concern: Deterministic Effects

- **Acute Exposure**: High dose delivered within seconds, minutes or days (have thresholds)

Some possible deterministic effects

Cataracts	***Skin damage***	Blood changes
Nausea	Diarrhea	Death

Cataracts

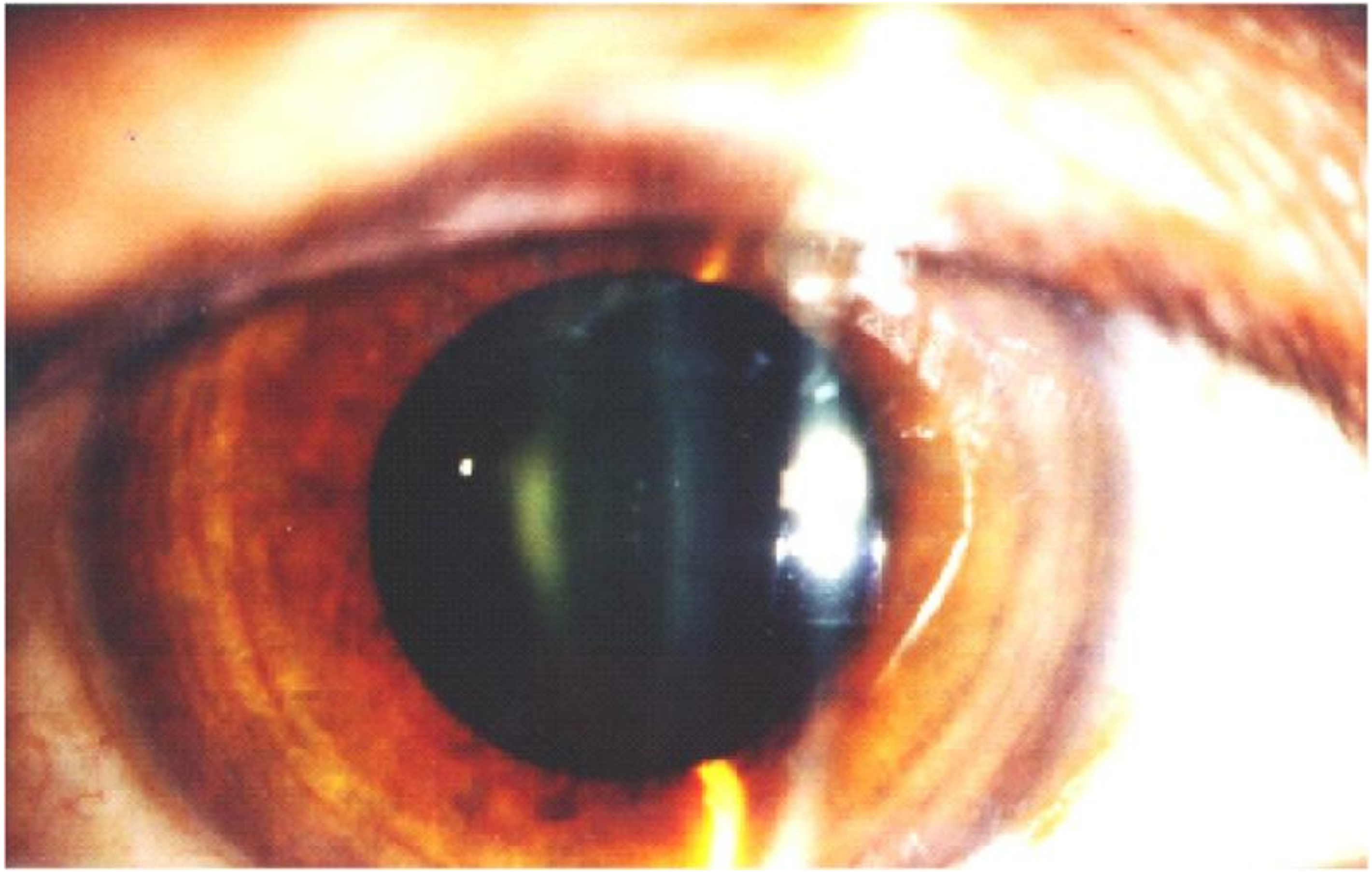
- Threshold: **0.5 Gy (500 mGy)**
  - *used to think the threshold was 8 Gy (8000 mGy)!*
- Currently, most provinces set the annual dose limit for the lens of the eye for designated workers:

150 mGy per year (based on the old 8 Gy threshold!)

- New ICRP recommendation:

20 mGy per year

Cataract in an Interventionalist



Posterior subcapsular cataract in the eye of an interventionist who used an old x-ray system and experienced high scatter radiation due to improper working conditions. *Source: Vano´ et al. (BJR, 71, pp 728-733, 1998).*

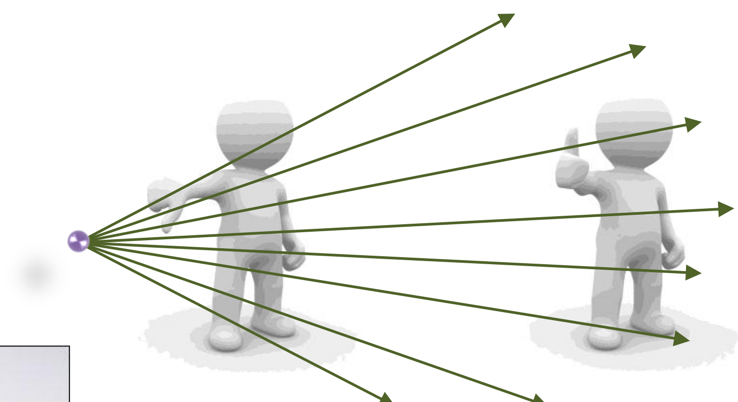
Radiation Protection

- The fundamentals of radiation protection are:
  - *Avoid* acute effects (high radiation doses resulting in immediate injury or death)
  - *Minimize the likelihood* of radiation-induced cancers
  - Keep radiation exposures ***As Low As Reasonably Achievable*** (ALARA)

Radiation Protection Principles

- External radiation exposure can be minimised by considering the following:
  - **Time**

  - **Distance**



  - **Shielding**

Lead bricks
Image courtesy of Radiation Protection Products, Inc.

Radiation Protection Tips: Fluoroscopy

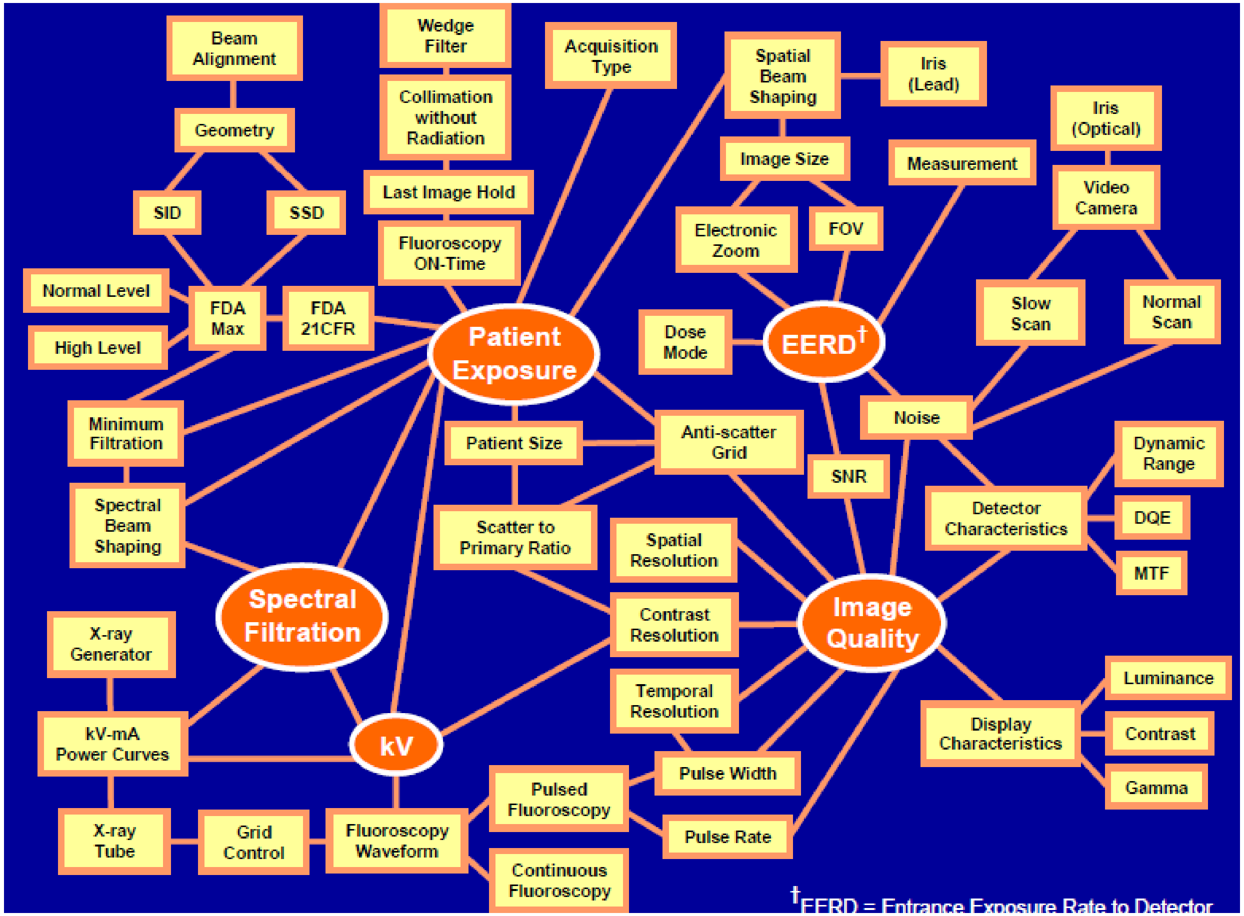
Fluoroscopy machines use an X-ray tube

- The patient is exposed to the **primary beam**
- Most of the radiation others receive in the fluoroscopy suite is from **scattered radiation**

Radiation exposure to **everyone** in the room is directly proportional to the ON-time of the unit

- Keep **tube current** (mA) as low as possible
- Keep **beam on time** (min) as low as possible

Dang, this is complicated…



Source: P. Rauch, Henry Ford Health Systems, 2008

Equipment considerations

Main equipment characteristics

- Flat panel (FP) or image intensifier (II) detectors
- Beam quality modulation through extra filtering
- Pulsed fluoroscopy
- Physical and virtual collimation
- Patient dose measurement

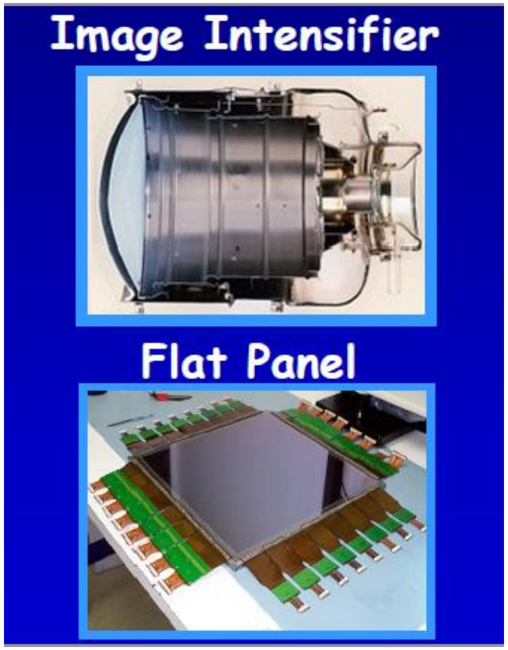


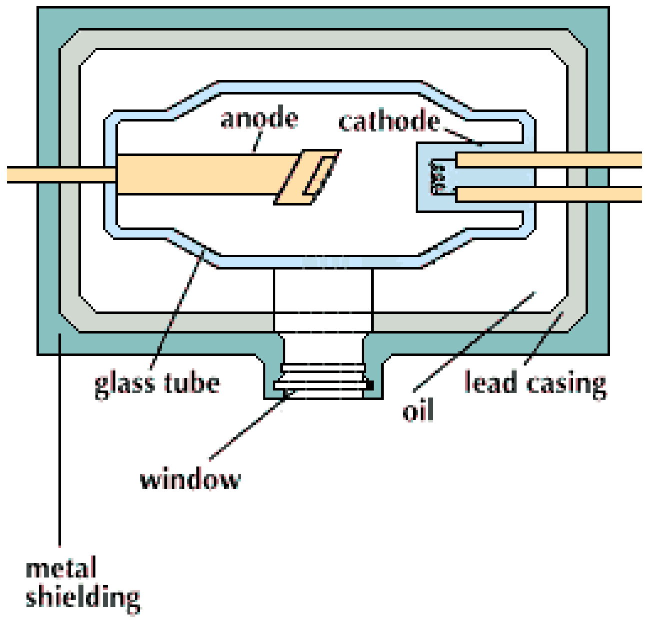
Image: P. Rauch, Henry Ford Health Systems, 2008

Flat panel vs Image Intensifier

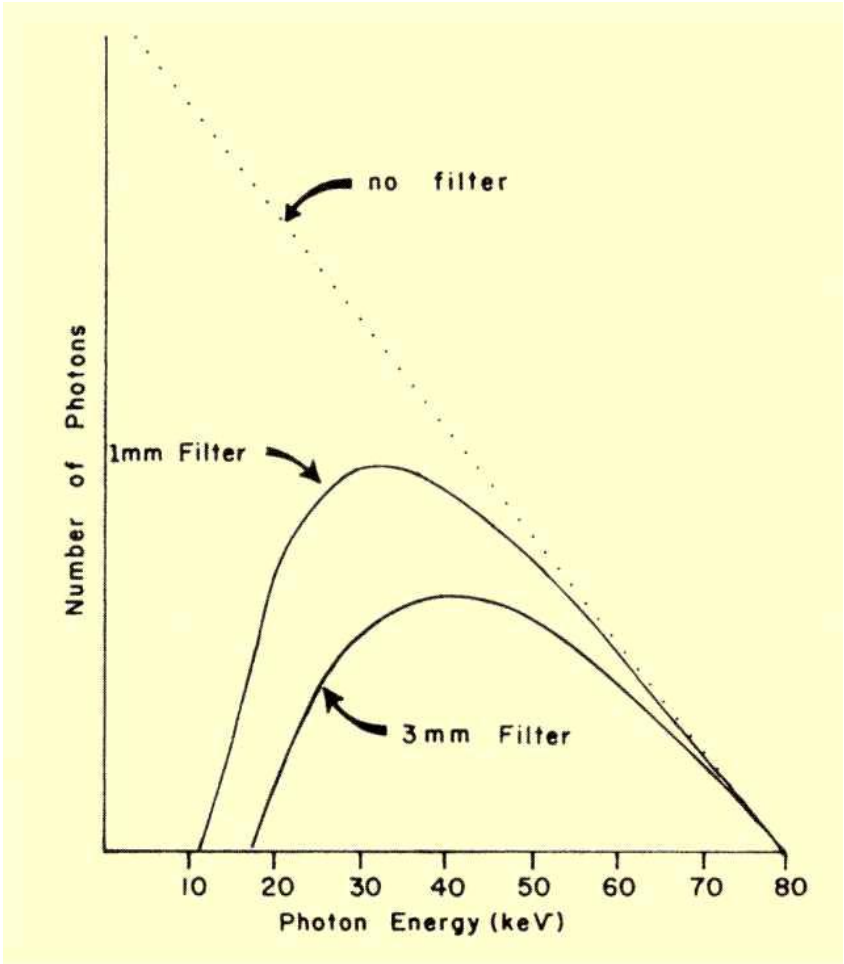
- Flat panels (FP) have
  - Higher sensitivity to x-rays (so lower dose is possible)
  - Better contrast resolution
  - Higher dynamic range
  - Distortion free images
  - Relative insensitivity to magnetic fields

Almost all fluoroscopic systems sold today are FP

Metal filters used to reduce low energy x-rays in beam



Modern fluoro systems automatically set extra x-ray beam filtration according to patient weight and the angulation of the C-arm
- Keeps skin dose low by removing low energy photons from the beam



Pulsed Fluoroscopy

- Pulsed fluoroscopy can reduce radiation dose, especially by selecting a low pulse rate
- It is **NOT** guaranteed that pulsed fluoro has a lower dose rate than continuous fluoro
- Dose depends on both the *dose per pulse* and the number of *pulses per second*
- Must increase dose per pulse as pulse rate is decreased
  - *Counters increased noise as pulse rate is decreased*
  - *Improves quality of last image hold (low noise + short pulse exposure time reduces image blurring)*
  - *More likely the operator will actually use the reduced pulse rate*

Other dose reduction

- Collimation of the x-ray beam to the area of interest (less dose to patient, less scatter to staff)
- Use of Last Image Hold (no fluoro)
- Selection of right operational mode for the procedure and task at hand

There is a wide range of acquisition modes leading to a wide range in patient and staff exposures

- One manufacturer's fluoro unit offers the following:
  - Acquisition rates: 0.5, 1, 2, 3, 4, 7.5, 10, 15, or 30 images/second
  - X-ray pulse width: 3 to 200 millisecond (changed automatically according to tube loading)
  - Automatically added filtration: 0, 0.1, 0.2, 0.3, 0.4, 0.6, 0.9 mm Copper
  - Dose rates at the detector ranging from 0.1 to 3.6 mGy/image (i.e., factor of 36)

Automatic Exposure Control (AEC)

- AEC modifies exposure parameters (kV, mA, pulse width, added filtration) as a function of:
  - Protocol selected
  - Imaging mode selected: fluoro (low, normal, high), cine, digital subtraction angiography (DSA)
  - Field of view (FOV)
  - Pulse rate
  - Patient body absorption

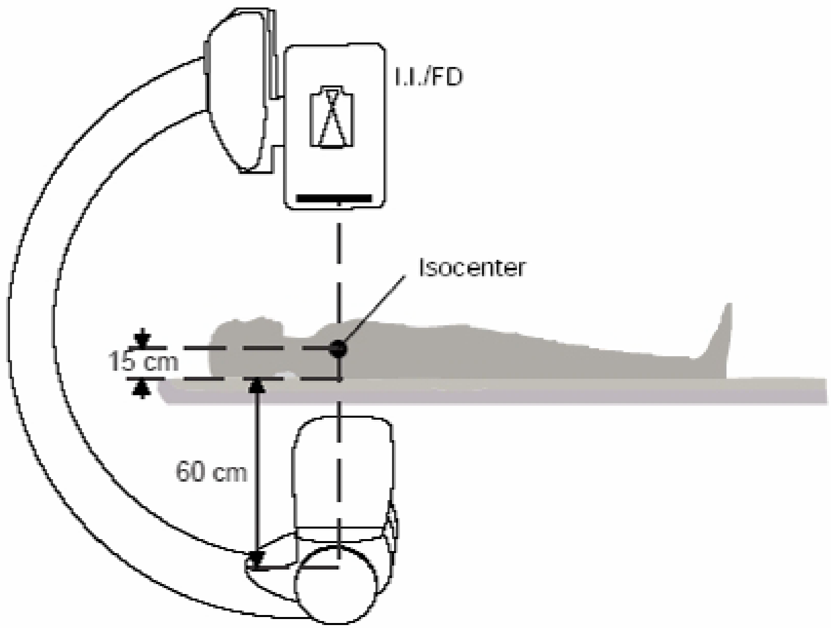
Patient dose is a function of the parameters selected

Patient Dose Metrics

- Quantities used for quality assurance and patient risk assessment:
- Cumulative Air Kerma-Area Product P_{KA} (KAP or DAP)
  - QA: comparison with reference values
  - Risk assessment
- Cumulative Air Kerma CK at the Interventional Reference Point (IRP)
  - To monitor skin exposure

Air Kerma at the IRP

- CK is defined as the incident air kerma accumulated at the interventional reference point (IRP)
- The IRP is a point assumed to represent the patient's skin at the x-ray beam entrance
- The IRP is located along the central ray of the x-ray beam at 15 cm from the isocenter towards the focal spot



Reducing skin injury

- Periodic measurements on equipment
- For new equipment and/or procedures, a “trigger value” in terms of a value available to the user during the procedure (could be CK to IRP or KAP) should be adopted to give the operator warning
- Procedure repetition on the same patient should be considered
- Follow-up protocol introduced for patients who could have received high skin dose

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IAEA Trigger Values

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	Trigger Values	
1	Fluoroscopy time	>60 min
2	KAP or DAP	>500 Gy-cm^2 or 50000 cGy-cm^2
3	$K_{a,r}$ (total air kerma at IRP)	>5 Gy or >500 cGy or >5000 mGy
4	Measured Peak Skin Dose	>3 Gy or >300 cGy or >3000 mGy
5	Number of series or cine runs	>20
	Trigger Events	
6	Observed radiation injury	
7	Wrong patient	
8	Wrong procedure	
9	Unknown pregnancy at time of the procedure	
10	Multiple procedures within 12 months	

Source: IAEA "SAFRAD" based values (SAFety in RADiological procedures reporting system)

Protection Basics

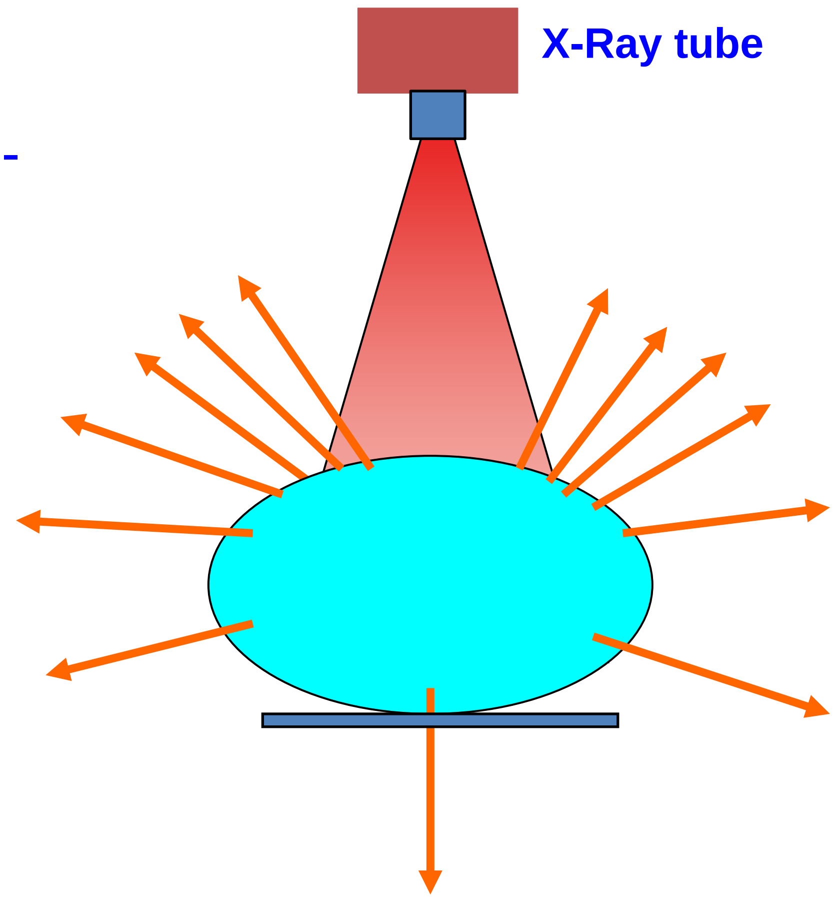
- Next few slides provide background and guidance on protection in the fluoro suite based on IAEA training material

Absorption and scatter

For every 1000 photons reaching the patient, about 100-200 are scattered, about 20 reach the image detector, and the rest are absorbed (= radiation dose)

Scatter x rays obey the Inverse Square Law, so distance from the patient improves safety

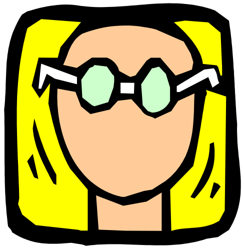
In radiology, scatter mainly directed towards the source



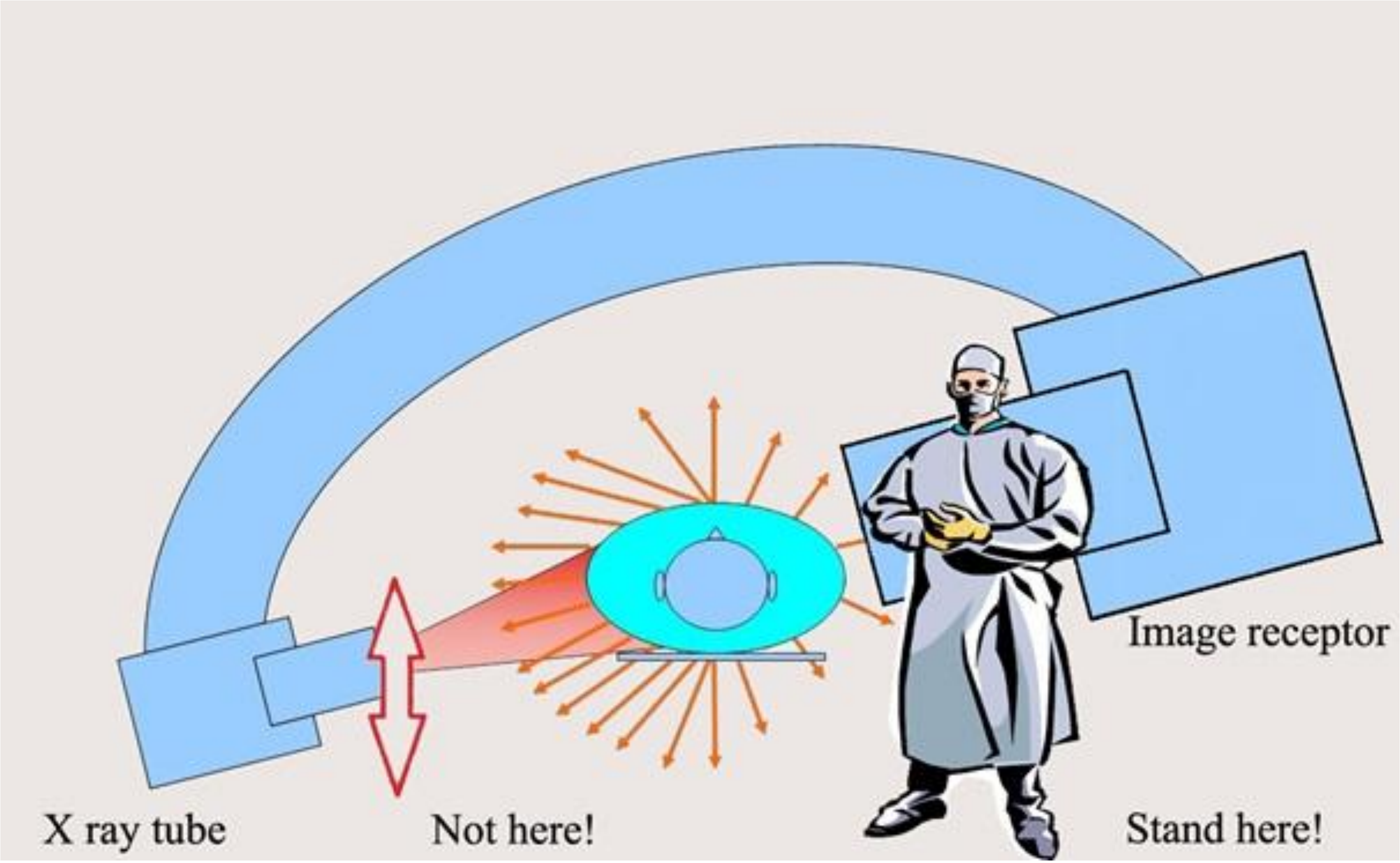
Source: IAEA training material

Factors affecting staff doses (I)

- The main source of radiation for the staff in a fluoroscopy room is the patient (scattered radiation).
- The scattered radiation is not uniform around the patient.
- The dose rate around the patient is a complex function of a great number of factors.



Stand on the image receptor side!

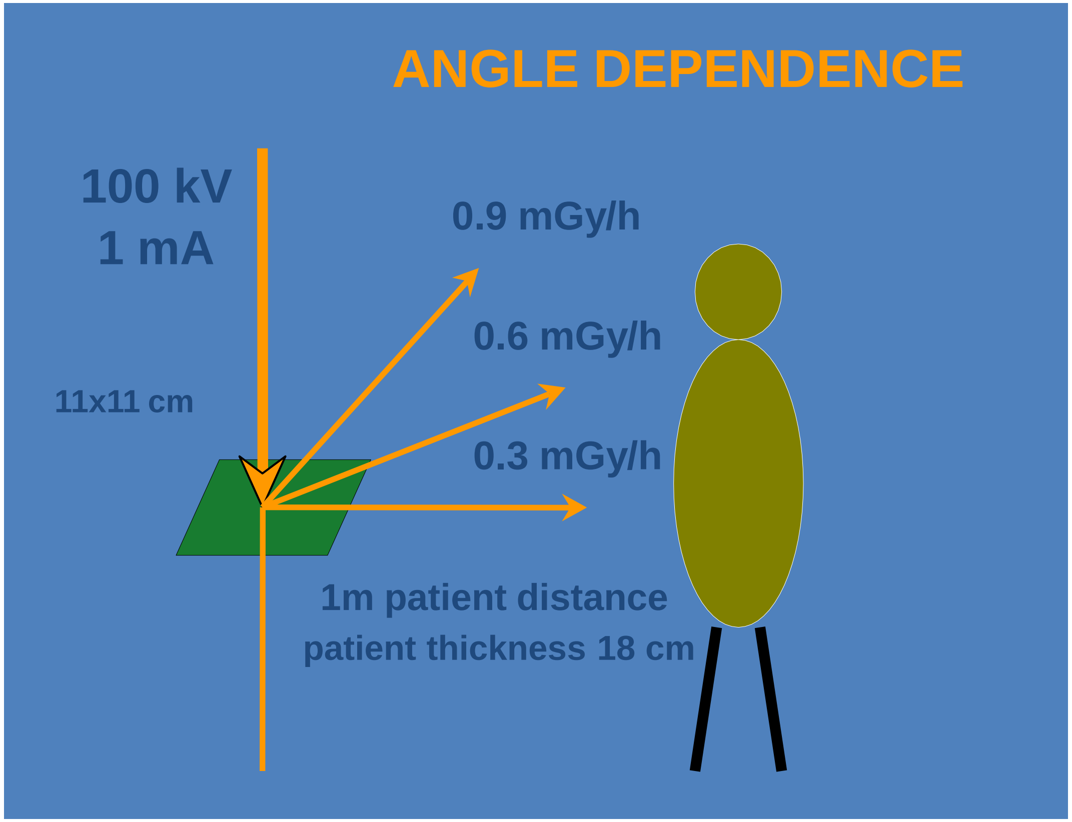


Factors affecting staff doses (II)

FACTORS AFFECTING STAFF DOSE

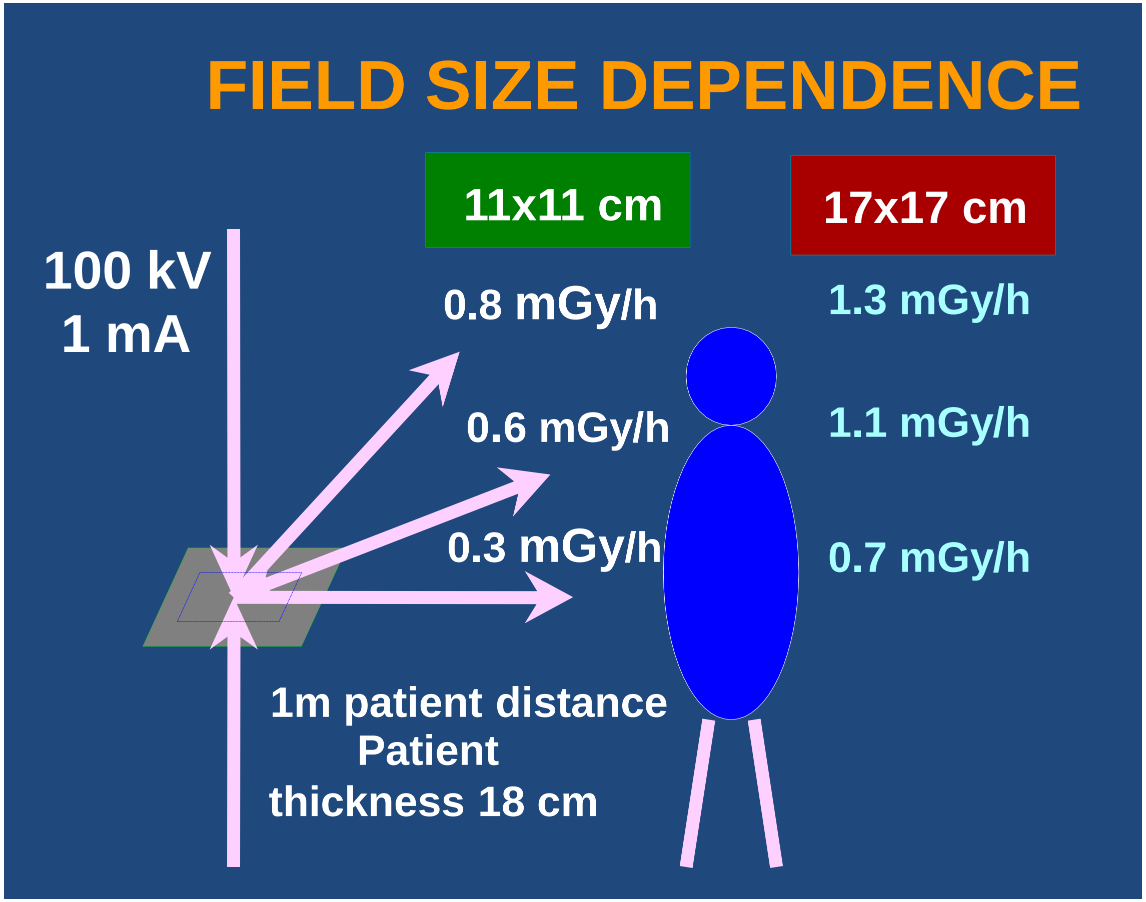
- **HEIGHT OF STAFF**
- **RELATIVE POSITION WITH RESPECT TO THE PATIENT**
- **IRRADIATED PATIENT VOLUME**
- **X RAY TUBE POSITION**
- **kV, mA and time (NUMBER AND CHARACTERISTICS OF PULSES)**
- **EFFECTIVE USE OF ARTICULATED SHIELDING AND/OR PROTECTION GOGGLES**

Factors affecting staff doses (III)



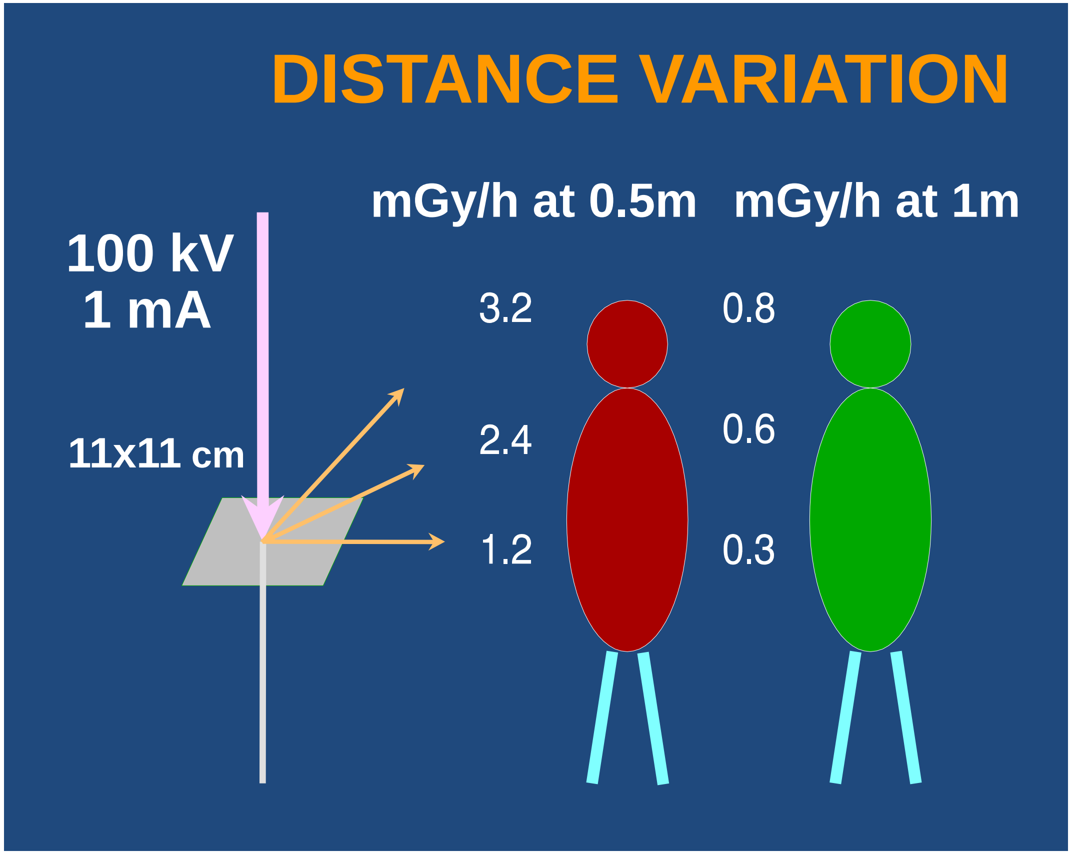
Scattered dose rate is higher near the area where the X-ray beam enters the patient

Factor affecting staff doses (IV)



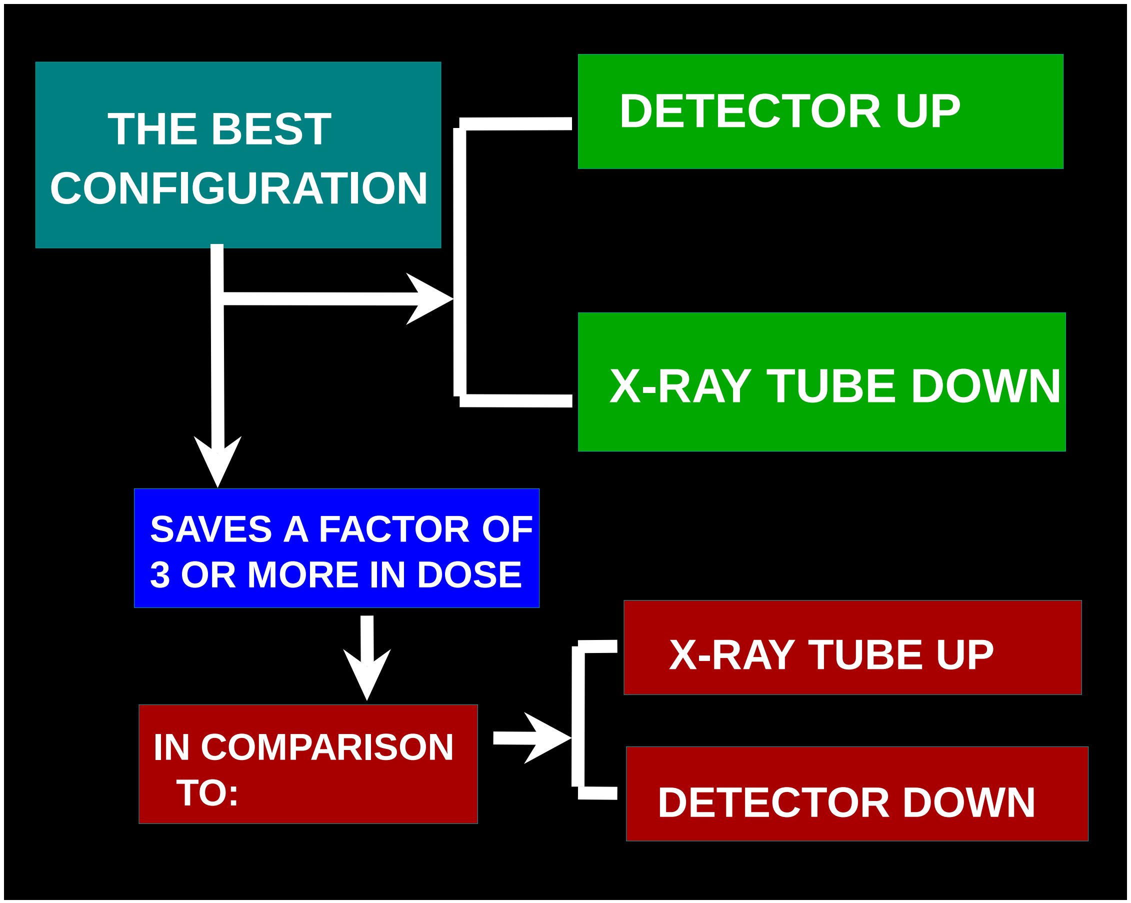
Scattered dose rate is higher when field size increases

Factor affecting staff doses (V)



Scattered dose rate is lower when distance to the patient increases

Factor affecting staff doses (VI)



Tube undercouch position reduces, in general, high dose rates to the operator's eye lens

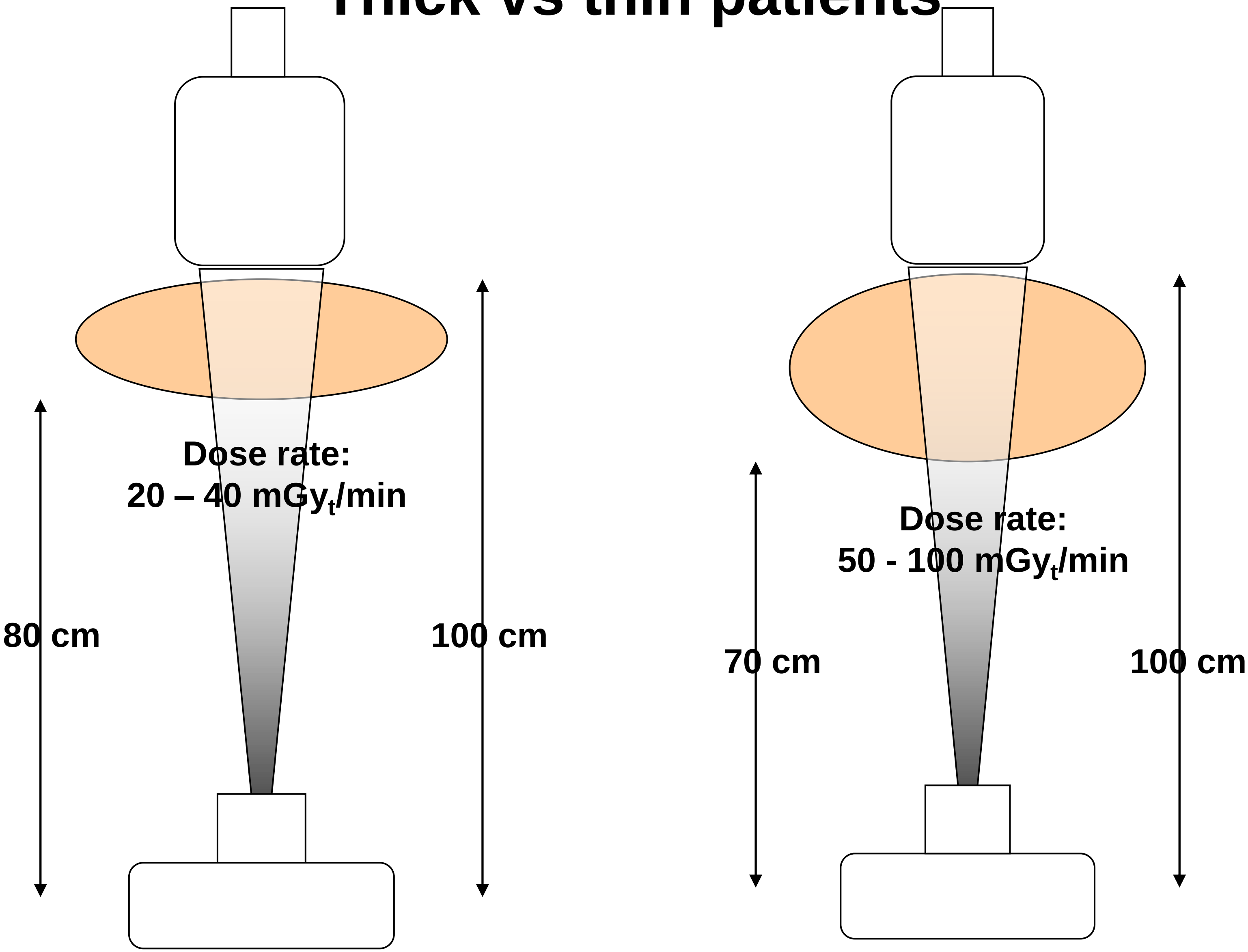
Factors affecting staff and patient doses (I)

IF PATIENT SIZE INCREASES

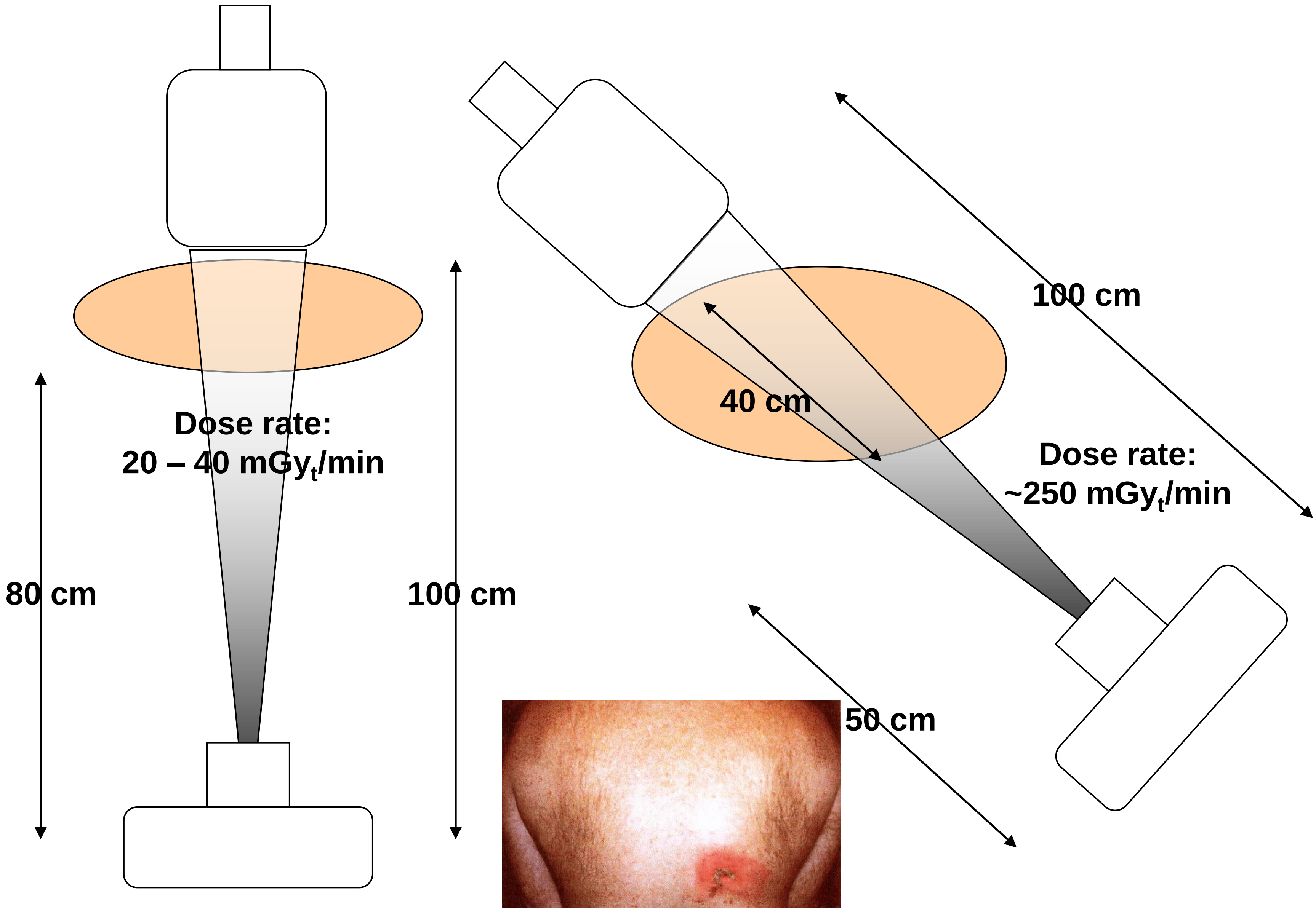
PATIENT SKIN DOSE AND THE LEVEL OF SCATTERED RADIATION INCREASE

SUBSTANTIALLY

Thick vs thin patients



Thick Oblique vs Thin PA geometry



Variation in exposure rate to the skin with projection

Projection	Fluoro entrance dose rate (mGy/min)	Cine entrance dose rate (mGy/min)
AP	31	388
RAO 30°	19	203
LAO 40°	20	216
LAO 40°, Cranial 30°	80	991
LAO 40°, Cranial 40°	99	**1236**
LAO 40°, Caudal 20°	29	341

(1) Pay attention to the angle used
(2) Have a good reason for cine runs!

(3) Note: the LD50 (whole body dose required to kill 50% of those exposed) is about 4500 mGy … cine is not exposing the whole body, but it could provide “lethal” levels of dose to areas of the skin in a few minutes

Adapted from Cusma et al 1999

Complex procedures may lead to high skin dose

Build-up of dose for a steeply-angled, high- dose rate beam through a large patient was not recognized during the procedure

Skin graft was required *(source: ICTP/IAEA Training Course on Radiation Protection of Patients, R Padovani)*

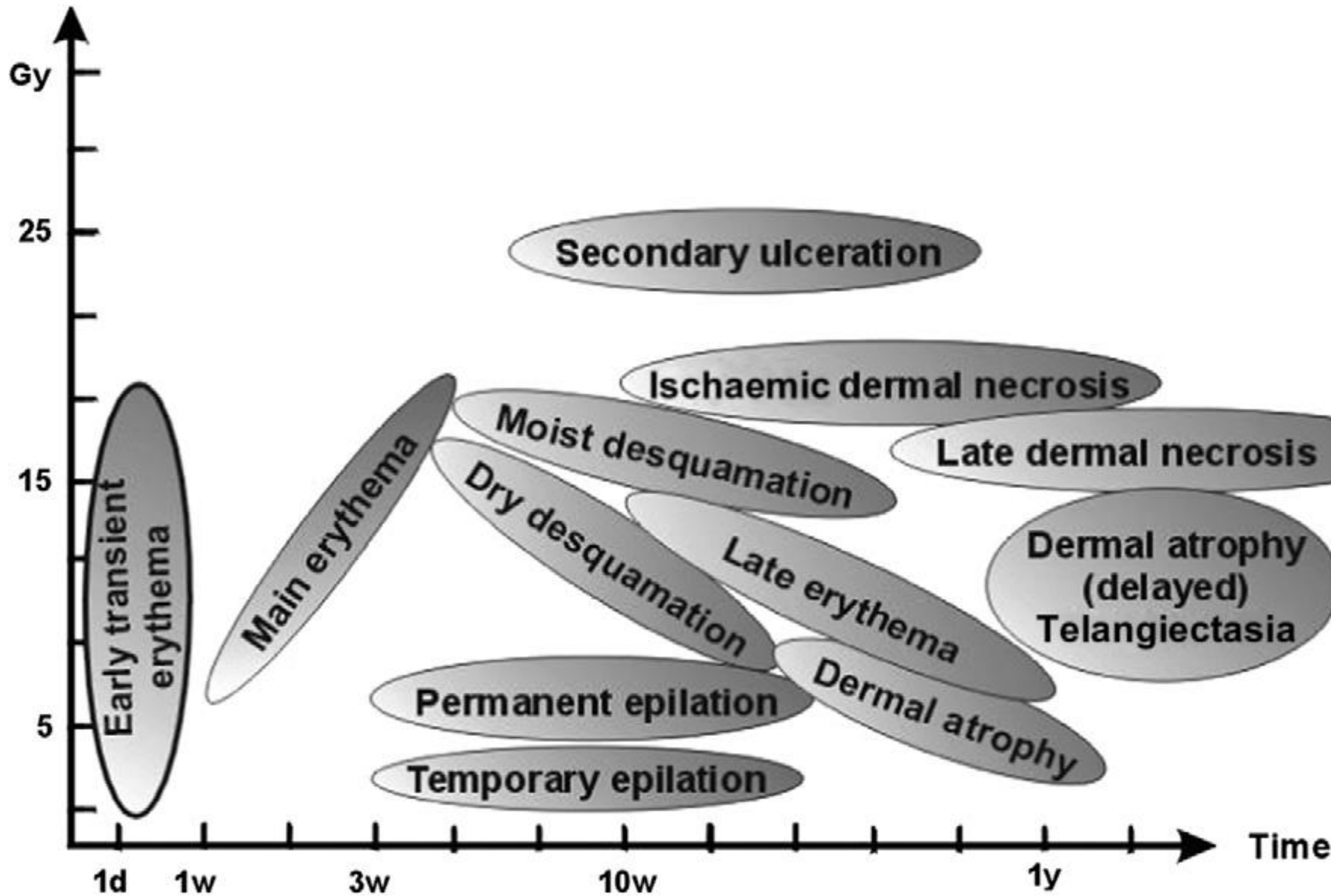
Fluoroscopy: Skin Dose

30 mGy/min not unusual

After 5 minutes, patient skin dose would be 150 mGy

2 Gy in 65 min
Skin damage!

Radiation Effects on the Skin



Overlap of radiation effects in the skin as functions of radiation dose and time post-exposure (*from ICRP Publication 120*)

Accidents: Fluoroscopy

From Imaging and Therapeutic Technology, Vol 1 No 5, p 1195, "Radiation-induced Skin Injuries from Fluoroscopy" Thomas B. Shope, PhD

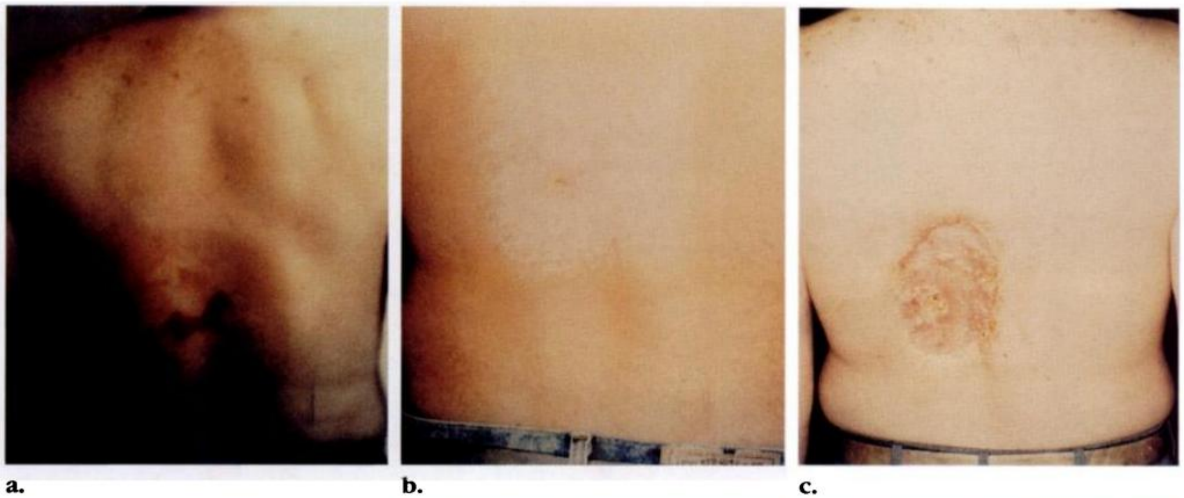
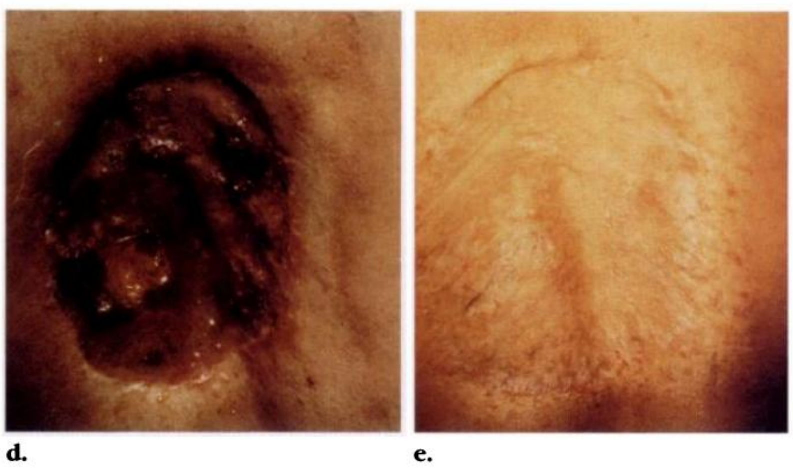


Figure 2. **(a)** Photograph of the patient's back 6–8 weeks after multiple coronary angiography and angioplasty procedures. **(b)** Photograph of the injury approximately 16–21 weeks after the procedures. A small ulcerated area is present. **(c)** Photograph of the injury approximately 18–21 months after the procedures. Tissue necrosis is evident. **(d)** Close-up photograph of the lesion shown in **c**. **(e)** Photograph of the patient's back after skin grafting.



Skin dose estimated to be > 20 Gy

Accidents: Fluoroscopy

- Be aware of patient position, including arms!

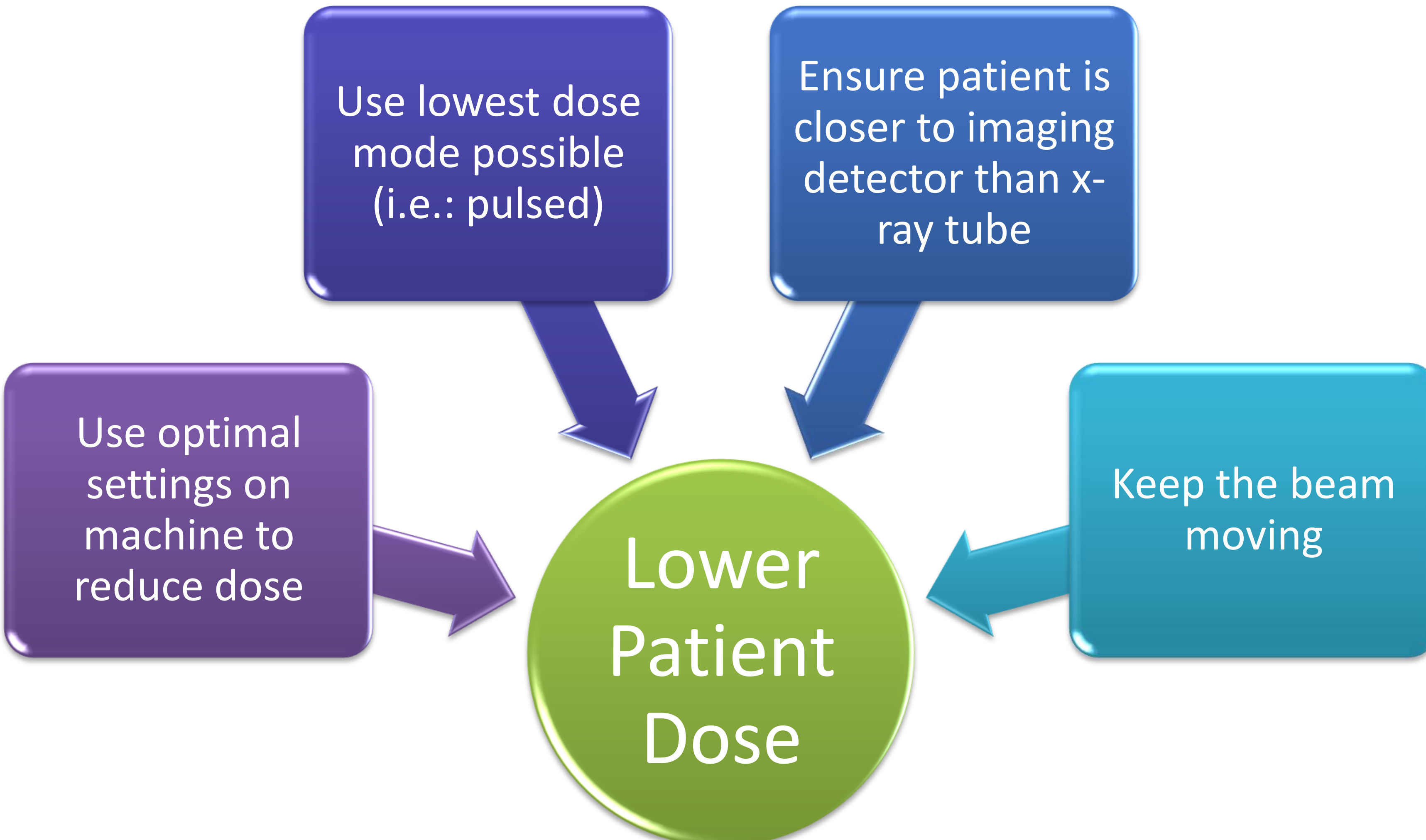
Patient rested her arm on the x-ray tube port (not noticed as the arm was under drape)

Wagner LK, Archer BR. J Am Coll Cardiol 2004; 44(11):2259-82

Accidents: Fluoroscopy

- Recommendations:
  - Establish procedures and protocols
  - Determine dose rates for the various operating modes
  - Assess each protocol for risk of radiation injury
  - Modify protocols or use equipment to reduce dose to skin
  - Record details of procedures to allow for assessment of dose

Patient Protection: Fluoroscopy



Factors affecting staff and patient doses (II)

CHANGING FROM NORMAL FLUOROSCOPY MODE TO THE HIGH DOSE

RATE MODE

INCREASES DOSE RATE BY A FACTOR OF 2 OR MORE

Factors affecting staff and patient doses (III)

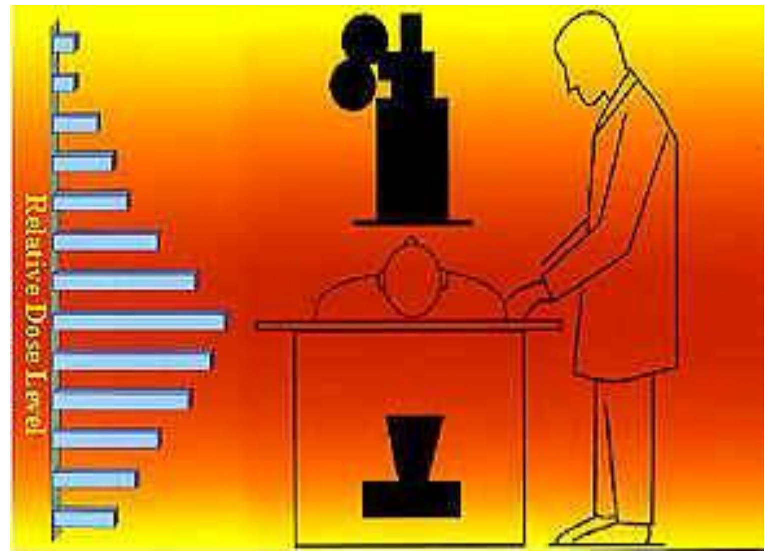
THE USE OF THE ANTISCATTER GRID

↑

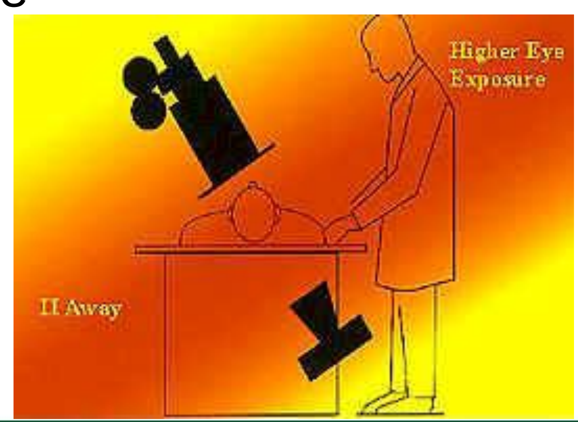
INCREASES PATIENT ENTRANCE DOSE BY A FACTOR OF 2 TO 6

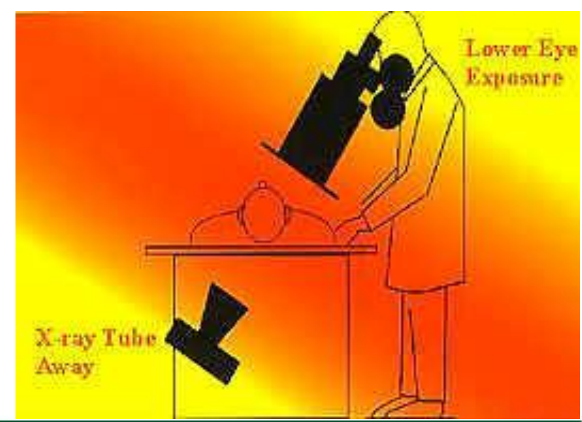
RP Tips for Fluoroscopy

- Be aware of everyone's positioning in the room



- The X-ray tube should be below the patient
- The detector should be as close to the patient as possible
- The X-ray tube should be pointed **towards** the operator, if possible





Scott Sorenson, 2000

Radiation Protection Tips: Fluoroscopy

Shielding and dosimetry are critical in fluoroscopy

Shielding:

- Lead curtains can be installed on the patient table
- Lead aprons should always be worn and should cover the thyroid, core, and reproductive area
- A lead glass screen will absorb scattered radiation
- **Goggles should be used to protect the eyes**

www.ultraray.com

Radiation Protection Tips: Fluoroscopy

- Caution!
- Lead equivalent gloves are not always beneficial
  - If hands are exposed to primary beam, may cause automatic exposure control to adjust settings and increase dose!

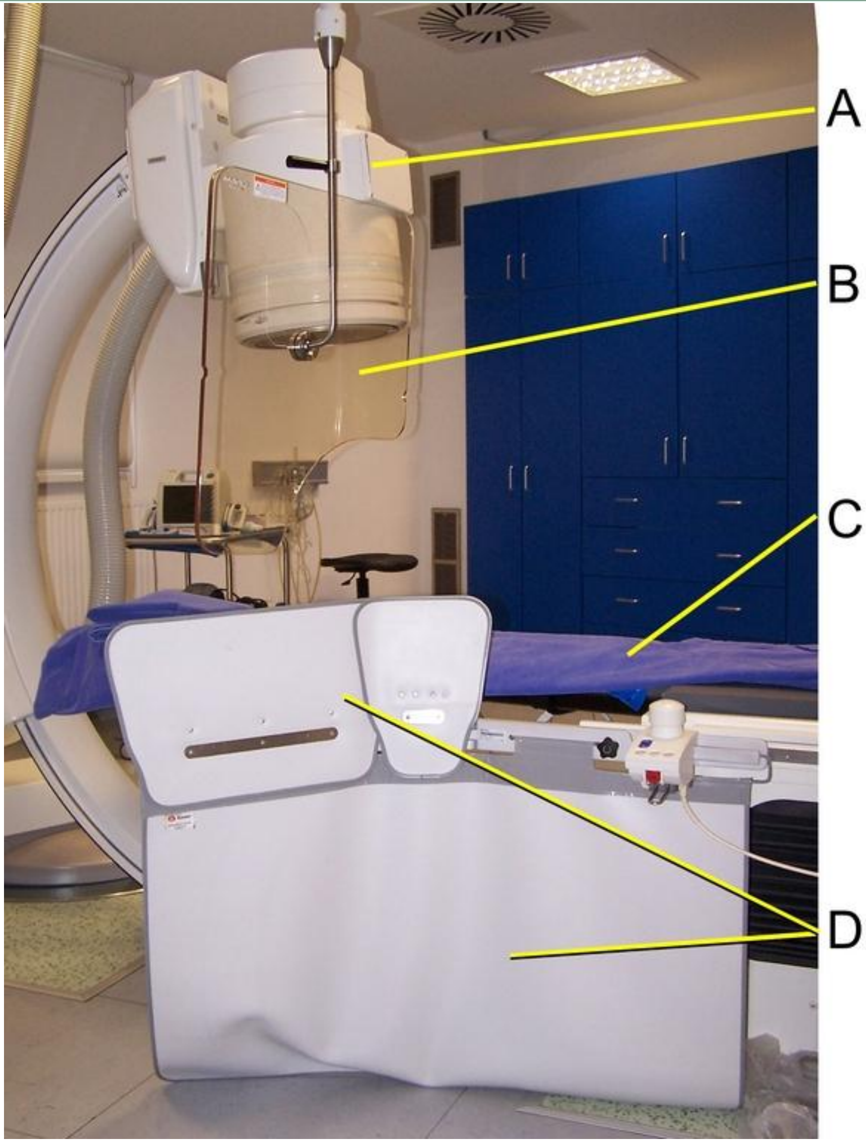
Radiation Shielding

A – image intensifier

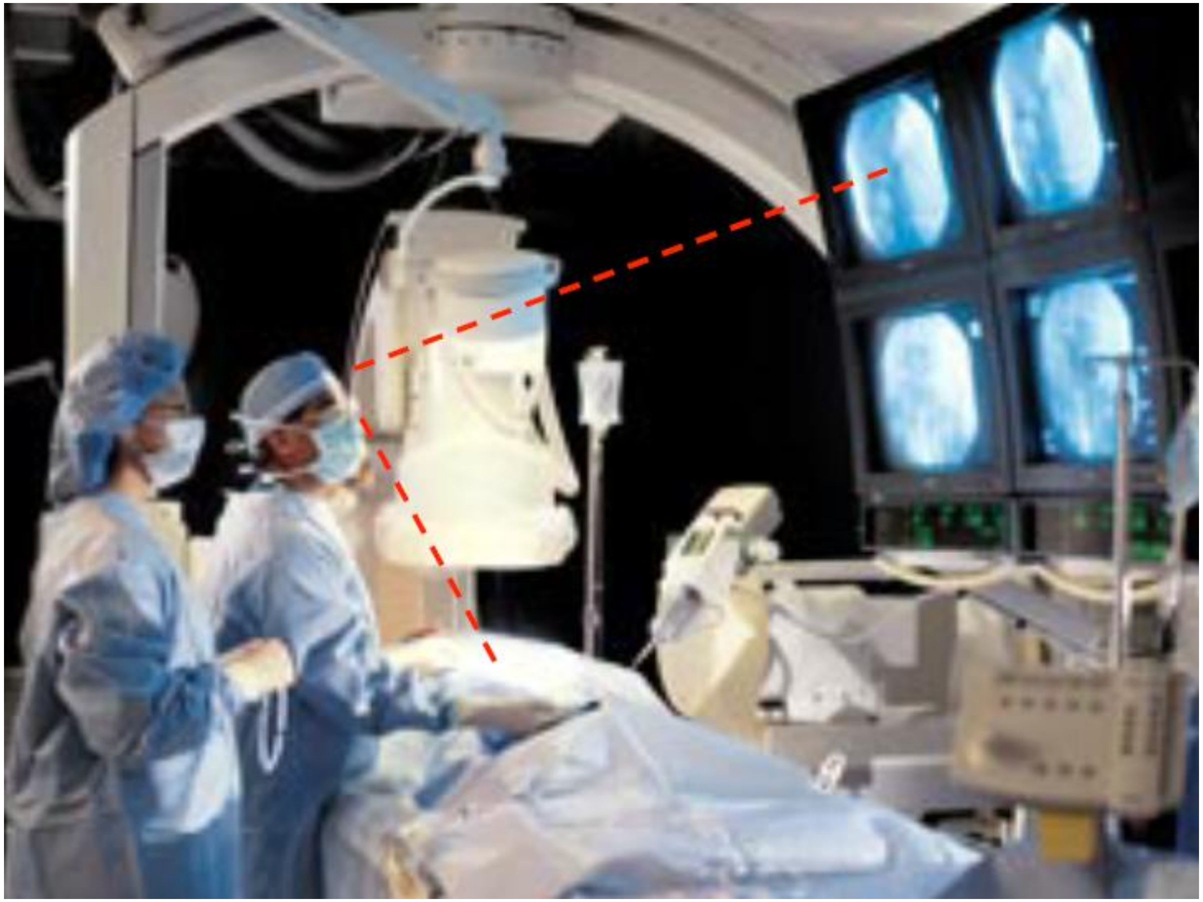
B – ceiling-mounted radiation protection screen

C – patient position

D – table-side shields



Factor affecting eye dose



X-ray scatter is mostly coming from below – while you look up, how well is your eye-protection working? *(source: ICTP/IAEA Training Course on Radiation Protection of Patients, R. Padovani)*

Effect of protective eyewear

T. Geber et al (Lund University, Sweden, Rad. Res. 2011) investigated the effectiveness of 8 types of protective eyewear

Remaining dose to the eye with eyewear

Eyewear (#)	1	2	3	4	5	6	7	8
Average Left TLD below (%)	72.4	43.0	77.5	84.8	86.1	22.4	35.1	69.7
Average Right TLD below (%)	98.2	89.1	96.8	93.8	96.6	89.2	87.6	92.0
Average Left TLD front (%)	17.8	14.4	27.1	26.0	22.5	14.3	15.5	20.0
Average Right TLD front (%)	17.0	13.0	24.7	26.1	23.7	17.1	18.9	16.6

Geber *et al's* results suggest that (1) there can be substantial differences among different types of protective eyewear and (2) it is essential that gaps be minimized and the eyewear mold around the face of the person in question (i.e., each individual should have their own, well-fitted, eyewear)

Dosimetry Tips for Fluoroscopy

Dosimeters

- One dosimeter should be worn **underneath** the apron
- Ring or bracelet dosimeters can keep track of dose to the hands
- One dosimeter should be worn on the collar, above the apron, to measure radiation to the eyes

Summary

- Fluoroscopy may lead to high radiation dose to patients and significant radiation dose to staff
- Modern fluoro units offer many options; selecting ones that can meet clinical objectives while maintaining low dose is non-trivial
- Reducing patient dose will often reduce scatter dose to staff
- Keep the x-ray tube at maximal distance from patient
- Use higher kVp where possible
- Wear protective aprons and radiation monitors, and know where scatter is highest
- Keep your distance, as far as is practicable

Resources

Web Sites

- Canadasafeimaging.ca
- www.radiationsafety.ca
- imagewisely.org
- imagegently.org
- radiologyinfo.org
- radiationanswers.org
- rpop.iaea/safrad/

Organizations

- Canada Safe Imaging
- Radiation Safety Institute of Canada
- ICRP
- NCRP
- IAEA

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Thank you for listening!

Curtis Caldwell, Ph.D.

Chief Scientist

Radiation Safety Institute of Canada

www.radiationsafety.ca

1-800-263-5803

info@radiationsafety.ca