Minimizing Risks from Fluoroscopic X-Rays

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United States Food and Drug Administration

- Advisory 1994 – Patient skin injuries
- Appropriate credentialing. Fluoroscopic operators must receive specific training on the unit(s) that they use, because radiation output and image quality controls differ among machines.
- Symptoms of radiation induced skin injury in a patient are most commonly delayed by days to weeks after the procedure.
- Radiation dermatitis is delayed, from weeks to years after the exposure
- No sensation of temperature rise
- ALARA As low as reasonably achievable
- Several procedures can result in very high cumulative doses

Image Quality, Dose, & Dose Rate

1. Patient size - dose rates are greater and dose accumulates quicker for larger patients
2. Tube current (mA) - keep the tube current as low as possible (decrease mA - increase noise)
3. Keep kVp as high as possible
4. Keep the x-ray tube at the maximal "reasonable" distance from the patient.
5. Image Intensifier as close to the patient as possible
6. Don't overuse image magnification (electronic or geometric)
7. Remove grid on small patients or large air gap
8. Always use tight collimation
9. Shielding (lead stored on hanger), position of personnel (inverse square rule), and monitoring (badges)
10. Keep beam-on time to an absolute minimum! – "The Golden Rule"

Dose

- Entrance skin dose is the dose located at the surface where the x rays enter the patient.
- Dose inside the patient is less and decreases by about a factor of 2 for each additional 4 cm of depth.
- Exit skin dose for a 25 cm thick abdomen is only about 1% that of the entrance dose.
- Principal source of radiation for the patient is the x ray tube.
- Principal source of radiation for the operator and other personnel is scatter from the patient.

Radiation quantities and units

Quantity	Units of measurement	What it is - (Definition)	What it measures	Why it's useful
Absorbed Dose	gray (Gy) or milligray (mGy)	Amount of energy locally deposited in tissue per unit mass of tissue	Measures concentration of energy deposition in tissue	Assesses the potential biological risk to that specific tissue
Effective Dose	sievert (Sv) or millisievert (mSv)	An attributed whole body dose that produces the same whole-person stochastic risk as an absorbed dose to a limited portion of the body.	Converts any localized absorbed or equivalent dose to a whole-body risk factor.	Permits comparison of risks among several exposed individuals, even though the doses might be delivered to different sets of organs in these individuals.
Air Kerma	gray (Gy) or milligray (mGy)	Kinetic energy released in matter	Measures amount of radiation at a point in space	Assesses the level of hazard at the specified location
Exposure (not used in this text)	millicoulomb·kg^{-1}	Ions of one sign produced by the radiation per unit mass of air	Measures amount of radiation at a point in space	Assesses the level of hazard at the specified location
Equivalent Dose	sievert (Sv) or millisievert (mSv)	A dose quantity that factors in the relative biological damage caused by different types of radiations.	Provides a relative dose that accounts for increased biological damage from some types of radiations.	This is the most common unit used to measure radiation risk to specific tissues for radiation protection of personnel
Dose-Area Product	Gy·cm^2, mGy·cm^2, or other similar unit	Product of air kerma and cross sectional area of x-ray beam	Measures how much radiation is employed for a fluoroscopic examination.	Can be used as a quality control measurement to assure that radiation is maintained within acceptable levels.

Adapted with permission from: Hirshfeld JW, et al. ACCF/AHA/HRS/SCAI clinical competence statement on optimizing patient safety and image quality in fluoroscopically guided invasive cardiovascular procedures: a report of the American College of Cardiology/American Heart Association/American College of Physicians Task Force on Clinical Competence. J Am Coll Cardiol 2004;44:2259–82.

1. Adsorbed dose is the most appropriate when assessing the potential for deterministic risk to the skin.
2. Effective dose is the most appropriate to use when comparing the risks for cancer among personnel whose bodies are exposed nonuniformly to x-radiation.
3. Units for Dose Area Product are Gy x cm^2

Dose

- Main Erythema occurs at 6 Gy, and @ 200 mGy/min. will occur in 30 min
- Ischemic dermal necrosis occurs at 18 Gy
- Dermal atrophy occurs at 10 Gy, and @ 250 mGy/min. threshold will be reached in 40 min.

Table 3. Potential effects in skin from fluoroscopy. (Adapted from Ref. 38 and revised according to information provided in private communication with J.W. Hopewell, 1999.)

Effect	Single-dose threshold(Gy_t)	Onset
Early transient erythema	2	~2 – 24 h
Main Erythema	6	~10 d
Temporary epilation	3	~3 wk
Permanent epilation	7	~3 wk
Dry desquamation	14	~4 wk
Moist desquamation	18	~4 wk
Secondary ulceration	24	>6 wk
Late erythema	15	8 - 10 wk
Ischemic dermal necrosis	18	>10 wk
Dermal atrophy (1st phase)	10	>12 wk
Dermal atrophy (2nd phase)	10	>1 y
Induration (invasive fibrosis)	10	
Telangiectasia	10	>1 y
Dermal necrosis (late phase)	> 12?	>1 y
Skin cancer	None known	>5 y

Dose

- Annual effective whole body dose limit for physicians 50 mSv
- Annual effective whole body dose limit for a visitor to the hospital 1 mSv
- Monthly dose limit to conceptus of pregnant worker 0.5 mSv (under-apron badge)
- Skin entrance dose rates in larger patients are generally greater than those to smaller patients because of the amount of tissue in the path of the beam is greater.
- Positioning the x-ray tube closer to the patient will increase the entrance skin dose.

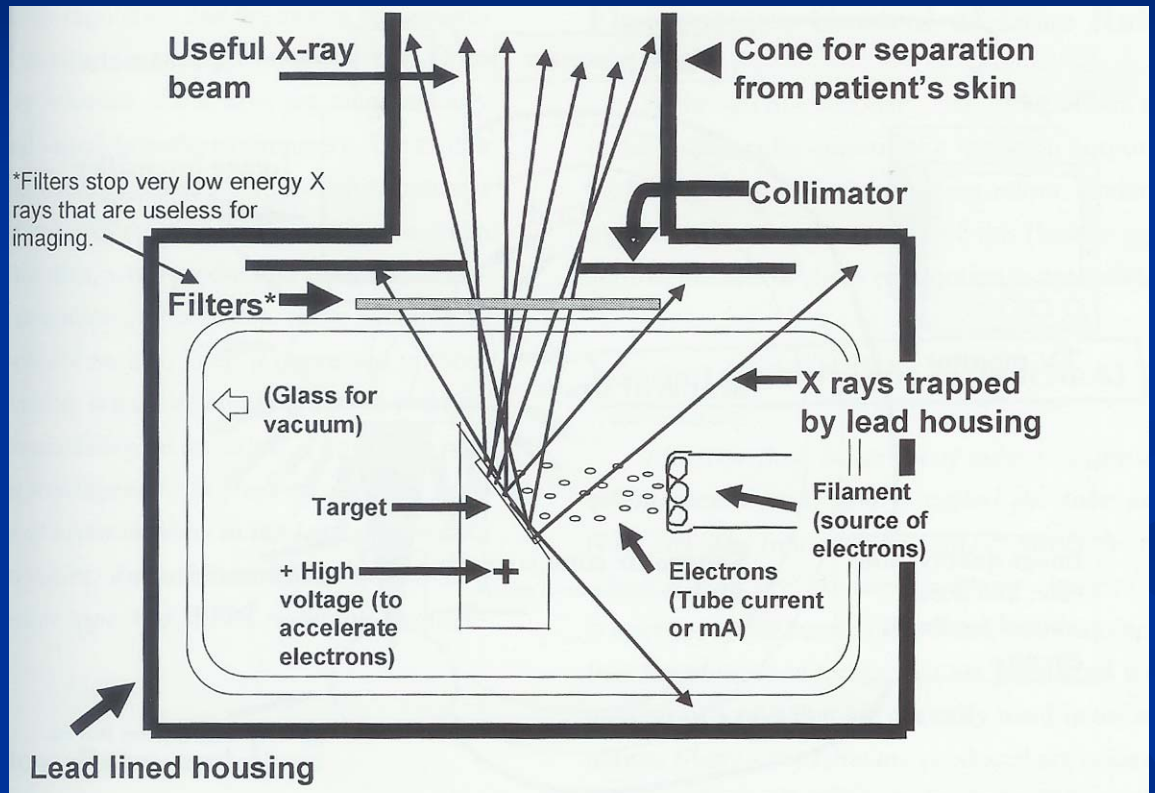
Biological Effects

- Stochastic effects include neoplasm and heritable changes in reproductive cells. (single cell)
  - Any dose, and the probability increases with dose.
  - (Anything above zero)
- Deterministic effects include radiation induced erythema, epilation, and necrosis. (multiple cells)
  - Threshold dose, i.e. a certain dose level must be reached
  - Threshold exists, and severity increases as dose increased beyond the threshold
- The principal threat to health from chronic very low level whole body radiation is radiation induced cancer.

Biological Effects - Unborn Fetus

- 0-2 weeks post conception – radiation induced loss of pregnancy
- 2-15 weeks small head size
- 8-15 weeks intellectual deficit and mental retardation
- Entire gestation – childhood cancers, particularly leukemia

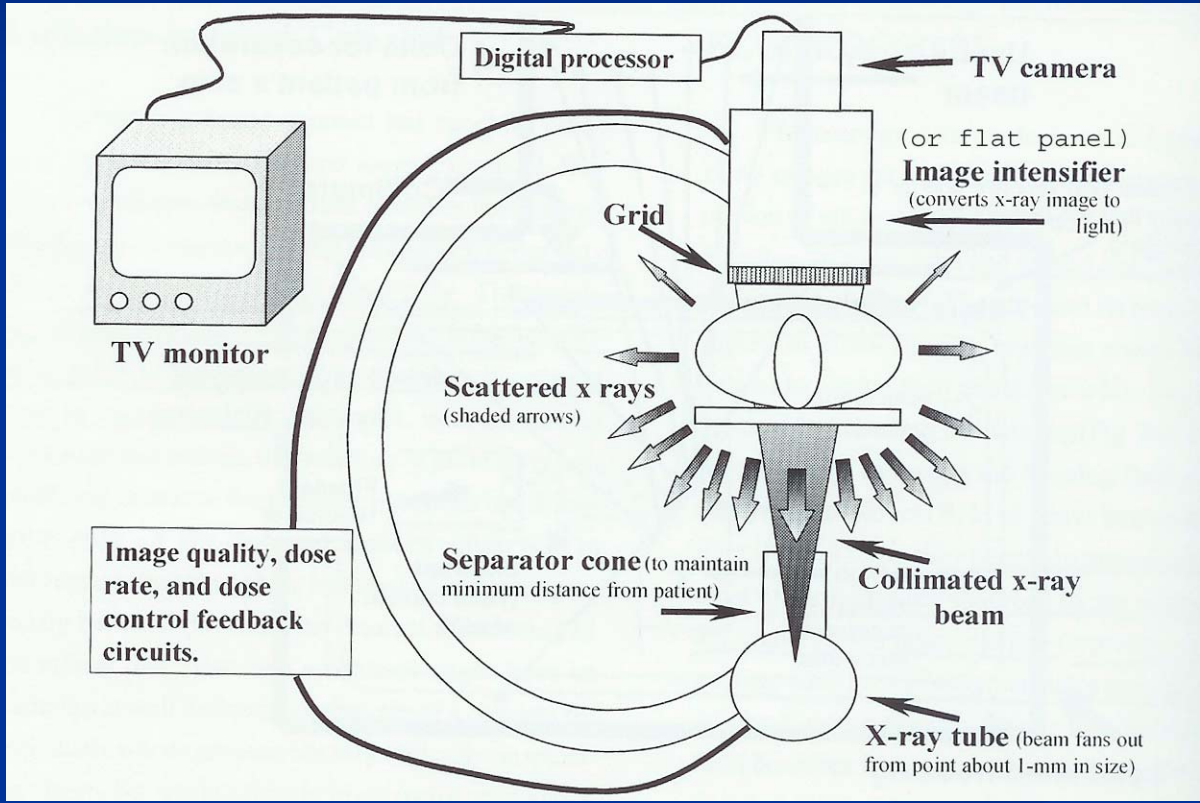
Equipment – X-Ray tube



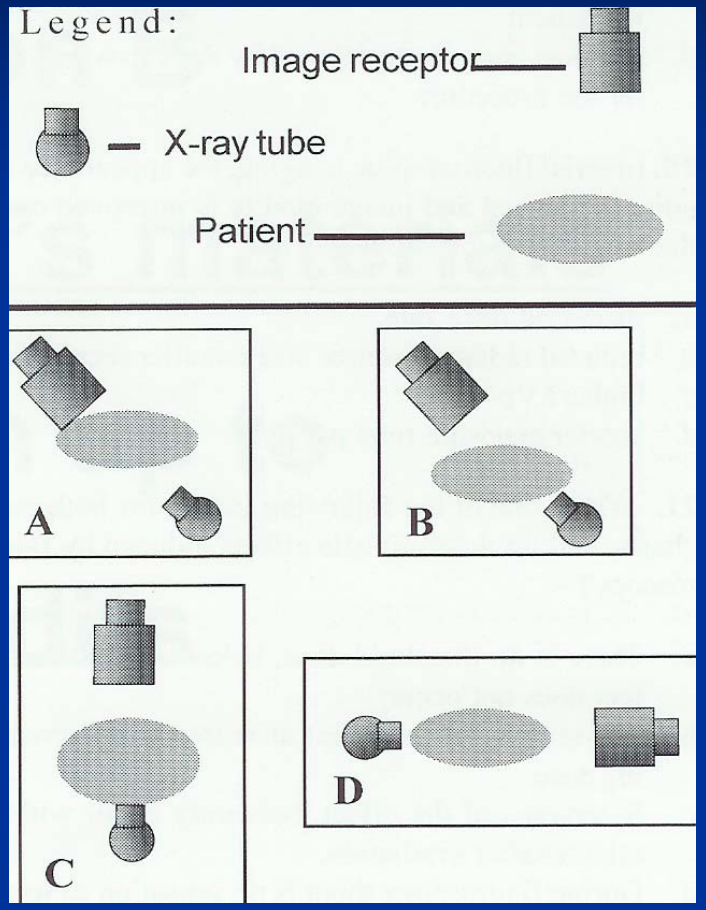
16. The x-ray tube and components related to radiation safety and x-ray beam management.

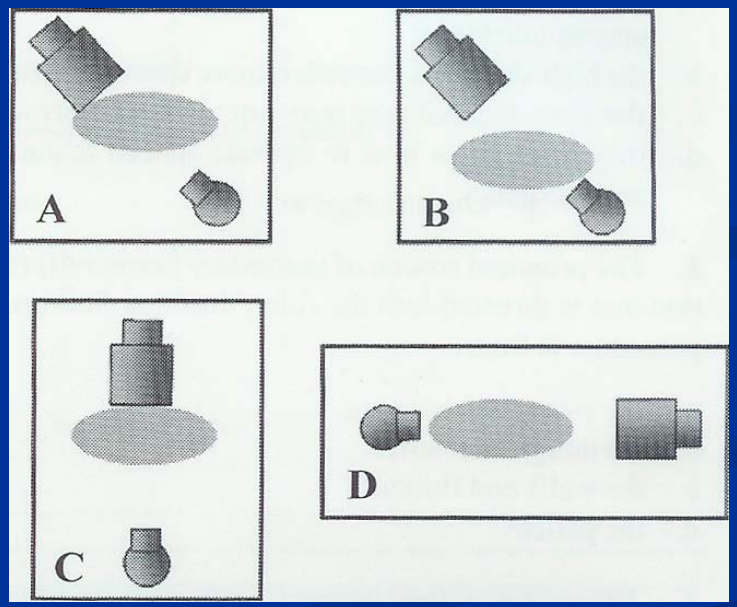
**<u>Filters remove poorly penetrating x-rays from the beam</u>

Equipment C-arm



Equipment - Question

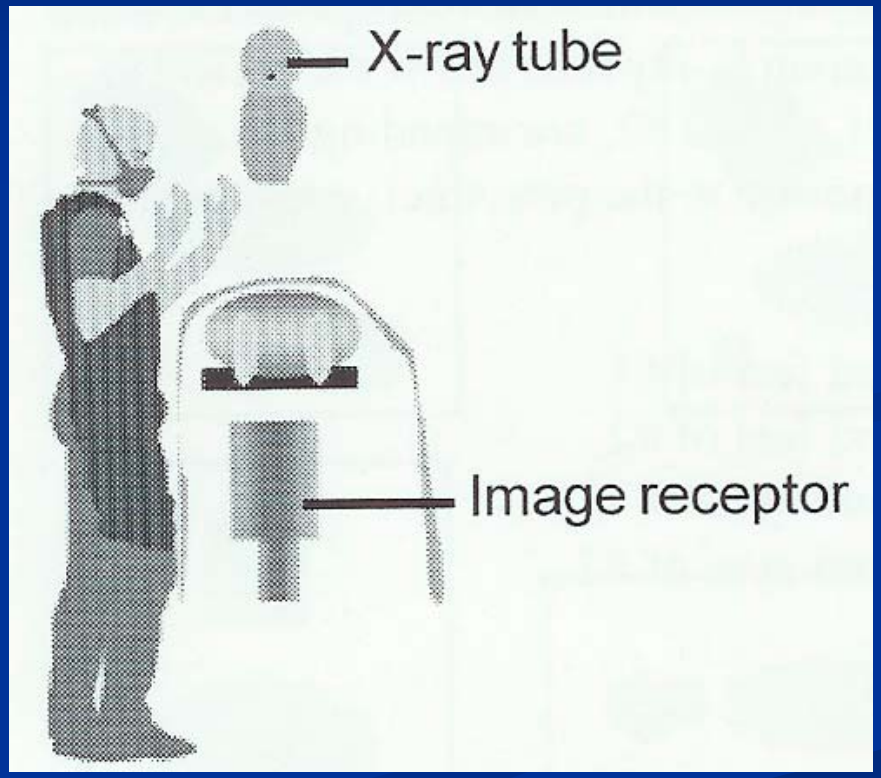




Skin entrance dose is increased when the x ray tube is positioned closer to the patient

Equipment - Question

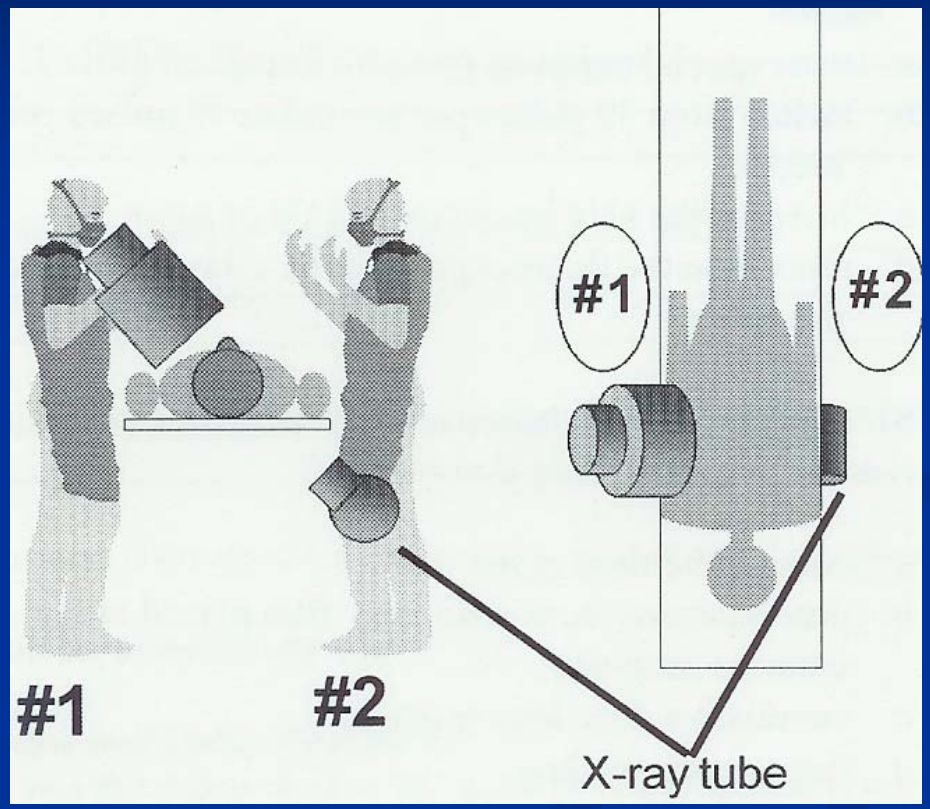
- In the vertical position, X-ray tube should be located beneath patient and the Image receptor above



- Routinely keep hands away from the imaged area and outside the housing of the image intensifier
- Monitor hand dose
- Step back
- Hand shields are not likely to protect hands if placed fully in the beam, as the automatic brightness control (ABC) will increase radiation output to penetrate the "protective gear"

Equipment

- In a lateral or oblique orientation, the x-ray tube should be positioned opposite the area where the operator and other personal are working
- II and operator should be on same side
- Patient as a shield



Highest dose will be to the legs and feet of #2

Collimators

- Collimators adjust size and shape of x-ray beam
  - lead shutters
- Reduces scatter radiation in the room
- Reduces scatter radiation to image receptor yielding better image contrast
- Lessens the radiation burden to the patient by reducing the volume of tissue exposed
- Does not reduce entrance dose rate to the skin. Reduces the area of skin exposed, the absorbed dose rate to the skin that remains exposed is likely to increase.

Monitor Dose to Patients

1. Fluoroscopy beam on time (Does not monitor radiation use from fluorography or effective collimation)
2. Dose area product (Does both and is therefore more effective quality control measure)
3. Cumulative air kerma at a fixed reference point (not as accurate as skin dose mapping monitor)
4. Cumulative peak dose at a site in the skin

Personal radiation dosimeter

- The most important reason for a fluoroscopist to wear a personal radiation dosimeter is to have a record of cancer risk later in life.
- Monitors exposures to radiation to identify whether safety should be improved.

Grids

- Grid is a flat plate devise that improves image contrast by selectively shielding the image intensifier from scattered x rays.
- Increases dose to the patient
- Increases scatter to personnel
- Using a grid will improve image contrast for an average adult patient undergoing automatic brightness controlled fluoroscopy
- Advantageous to remove the grid in Pediatric patients or small adults and when there is a large air gap.

Fluoroscopic Timer

- A 5-minute cumulative timer is required on all fluoroscopic units to remind the operator audibly of each 5-minute time interval

Cataracts

- Cataracts are a potential risk for patients undergoing high-dose interventional procedures in the head
- The threshold for radiation-induced cataract is about 1 Gy

Thoracic Fluoroscopy in Women

- Breast cancer has been induced in women
- These women, for the most part, were positioned with their breasts facing the x-ray tube
- Position the beam so that the breast is not in direct line with the x-rays or consider using tape or bandages to move some of the breast out of the direct x-ray beam

Other

- Pulsed fluoro (30, 15, 7.5 and 3.75 pulses per second) reduces dose dramatically over continuous fluoro techniques.
  - Decreased radiation output per pulse of pulsed fluoro results in a nosier image.
- In variable pulsed fluoro: the x-ray beam is pulsed at a selectable number of times/sec, dose rates are lower for lower pulse rates, the dynamics of motion are less fluid the lower the pulse rate
- Try to avoid long exposure time to same skin area
- Try to avoid high skin dose modes of operation such as cine, high- level control if possible
  - High level control boosts radiation output beyond standard levels and can be a dangerous mode.
- Real-time dose monitoring is now standard on most newer fluoroscopic/angio/interventional systems
- Don't allow any extraneous body parts in the beam