

Fluoroscopy and Radiation Safety

Jackie Rowles, CRNA, MBA, FAAPM
Meridian Health Group

Fluoroscopy defined

- study of moving body structures
- An x-ray “movie”
- A continuous beam passes through body and is transmitted to a monitor for viewing

Fluoroscopy

- LIVE images generated by x-ray allow proceduralist to see patient's internal bony structures
- Medical irradiation is the greatest source of man-made radiation in the US

Fluoro risks

- FDA reported 60 cases of radiation burns in patients between 1994-2001
- Physicians using fluoro and other radiography had the highest rate of cancer related deaths among their peers in the first half of the 20th century

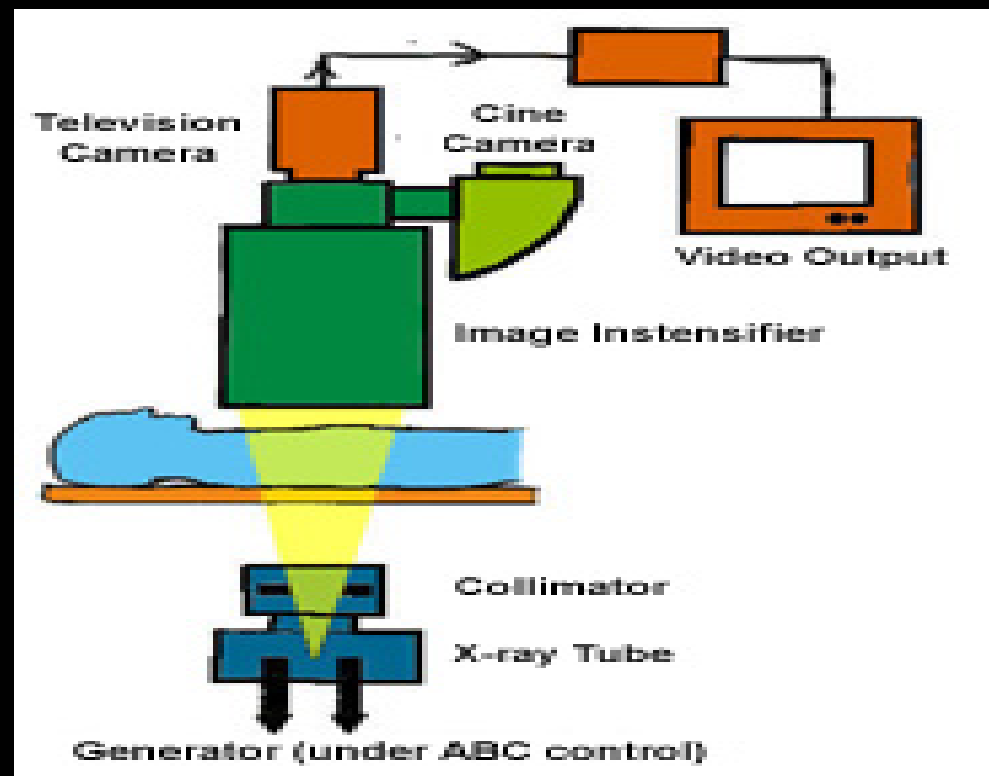
History

- First observed by Roentgen in 1895.
- X-rays strike a screen coated with fluorescent material
- Radiation blocked by denser tissue (bone) so see dark shadow of bone on screen against a light background

Historical Use

- 1950s in FP offices
- Shoe stores— to determine shoe size
- 1960s image intensifier produced—allowing for brighter images at lower radiation doses

Fluoroscopy



Benefits of Fluoroscopy

- Allows for precision of pain source identification and targeted injection
- Can perform procedures more safely at all spinal levels and throughout the body
- Risk of injection is minimized in patient's with difficult anatomy
- Radiologic documentation of drug delivery
- Smaller gauge needles can be used resulting in less pain
- Procedures may be completed more quickly

Physics of radiation

- Current (quantity of electron flow) is measured in milliamperes (mA)
- Rate of x-ray production is related to the electron flow
- Higher mA means more electrons strike the tungsten target, producing more x-rays
- Electrons decelerate in the target (patient)

Physics of radiation

- Most of the energy from the decelerating electrons is NOT converted into x-rays but dissipates as heat
- Heat must dissipate for continued x-ray production or there is a delay
- X-rays emit uniformly and in all directions

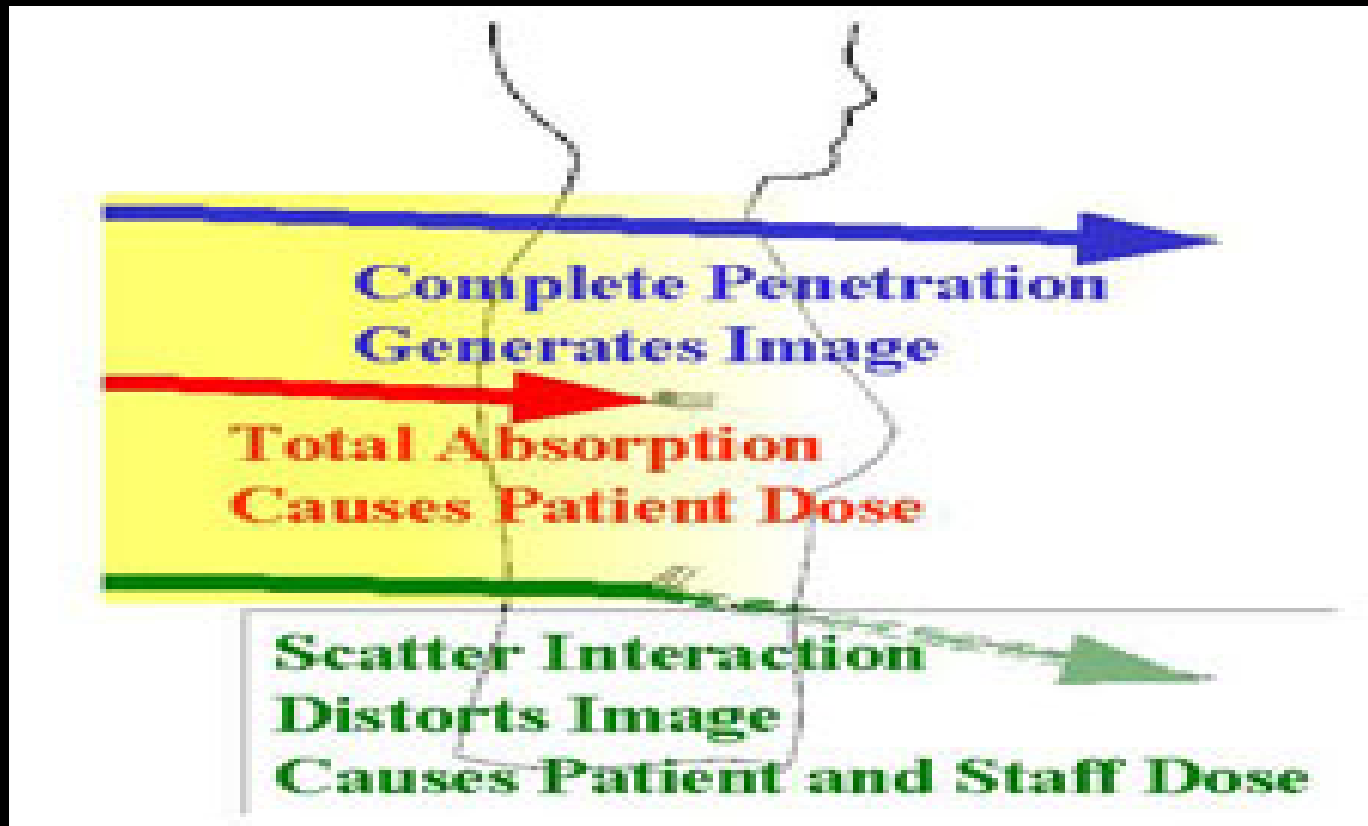
How x-rays interact with matter

- No interaction—pass through tissue directly into recorder
- Complete absorption—energy fully absorbed by tissue. No imaging seen. Is how the patient is exposed.
- Partial absorption and scatter—partial energy transfer to tissue. Scatter = less x-ray energy and different trajectory. Image distortion occurs. Causes staff exposure.

X-ray transfer

- X-rays not reaching the image recorder are absorbed in the patient (patient radiation dose) or scattered in the area (staff radiation dose)
- Radiation causes cellular damage as it carries energy into tissue

X-Ray transfer



Radiation Interaction with material

- Dependent upon tissue electron density
- Tissue thickness
- X-ray energy – amount or exposure measured by the concentration of free electrons per unit mass (roentgens)

Effects of Density

- Dense material (bone, contrast dye) attracts more x-rays from the beam resulting in darker image
- Muscle, fat , air are less dense and result in lighter image
- Different rate of attenuation is what provides the contrast needed to form an image

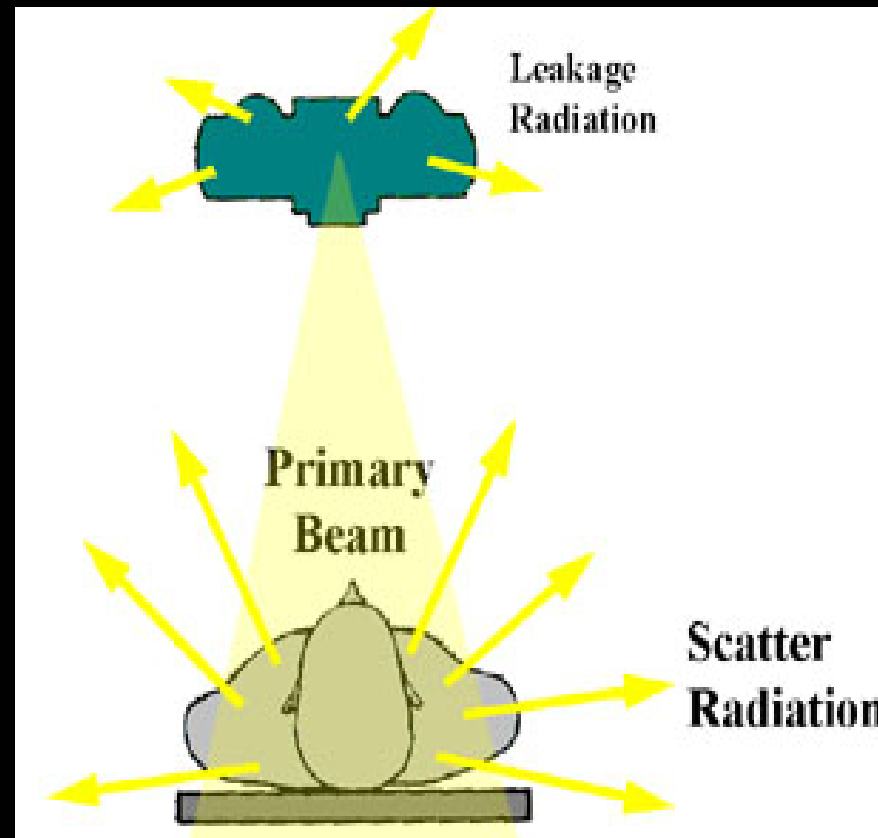
Example: 20 cm thick patient

- 1% x-rays reach the image intensifier
- 99% x-rays being generated are absorbed within the patient or scattered in the room.
- Human tissue is the primary medium that absorbs the radiation

Radiation absorption

- Absorbed dose is defined as the quantity of energy that an ionizing radiation gives off to a set mass of matter
- The unit of absorbed dose is the RAD or Gray (Gy)
- Size of the radiation dose (absorption) is due to the strength, distance from patient and the time of exposure

Scatter



Fluoroscopy Limitations

- Radiation exposure (patient and team)
- Need for repositioning to obtain planar views

Inverse relationship of Radiation exposure (inverse square law)

- Doubling the distance from a radiation source results in decreased radiation exposure by one-fourth. However, halving the distance to the source results in a four-fold increase in radiation exposure!

X-ray output

- ESE—Entrance Skin Exposure
- Amount of radiation delivered to the skin at the entrance point of the beam
- Units of ESE are known as roentgens per minute (R/min)
- Voltage is adjustable from 50-120 kV.
- Current Fluoro setting usually ranges 0.5-5 mA
- Newer fluoro units have ABC control

Voltage and Current

- Voltage effects contrast
- Current effects brightness
- ABC automatically adjusts kVp and mA so you get the best image at the lowest possible settings

Radiation exposure

- Patient—units of rad (amount of energy imparted per unit of tissue mass).
Immediate biological effects from radiation described in term of Rad or Gray (gy)
- Personnel—Rem. Also a radiation dose
Increasing Rems are correlated with increased risk of latent health effects
- $1 \text{ rad} = 1 \text{ rem}$. $1 \text{ Gy} = 100 \text{ rads}$

Dosimetry badges

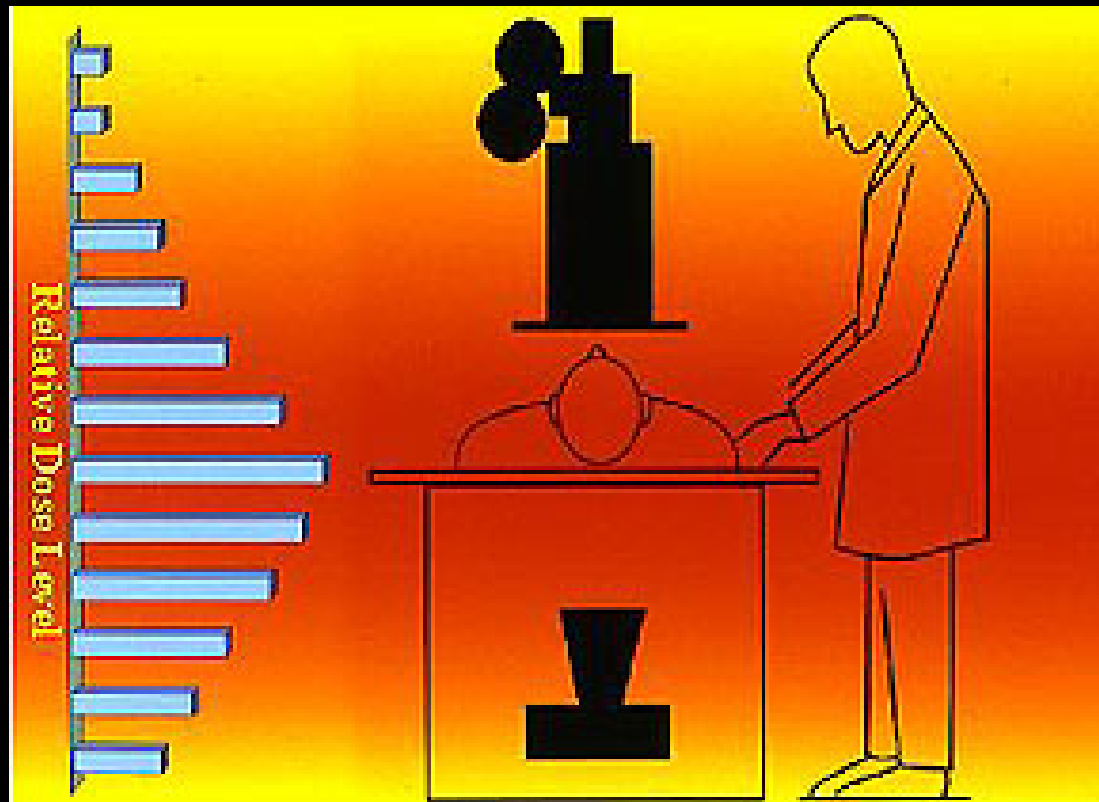


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- Major source of staff radiation is scatter from the patient
 - Scatter intensity decreases with distance away
 - Scatter is highest near its source
 - Radiation levels are lower above the table

Radiation exposure

- Highest level of body exposure for staff is waist and thighs
- Lead aprons protect up to 80% body's vital organs, decrease radiation exposure by up to 90%

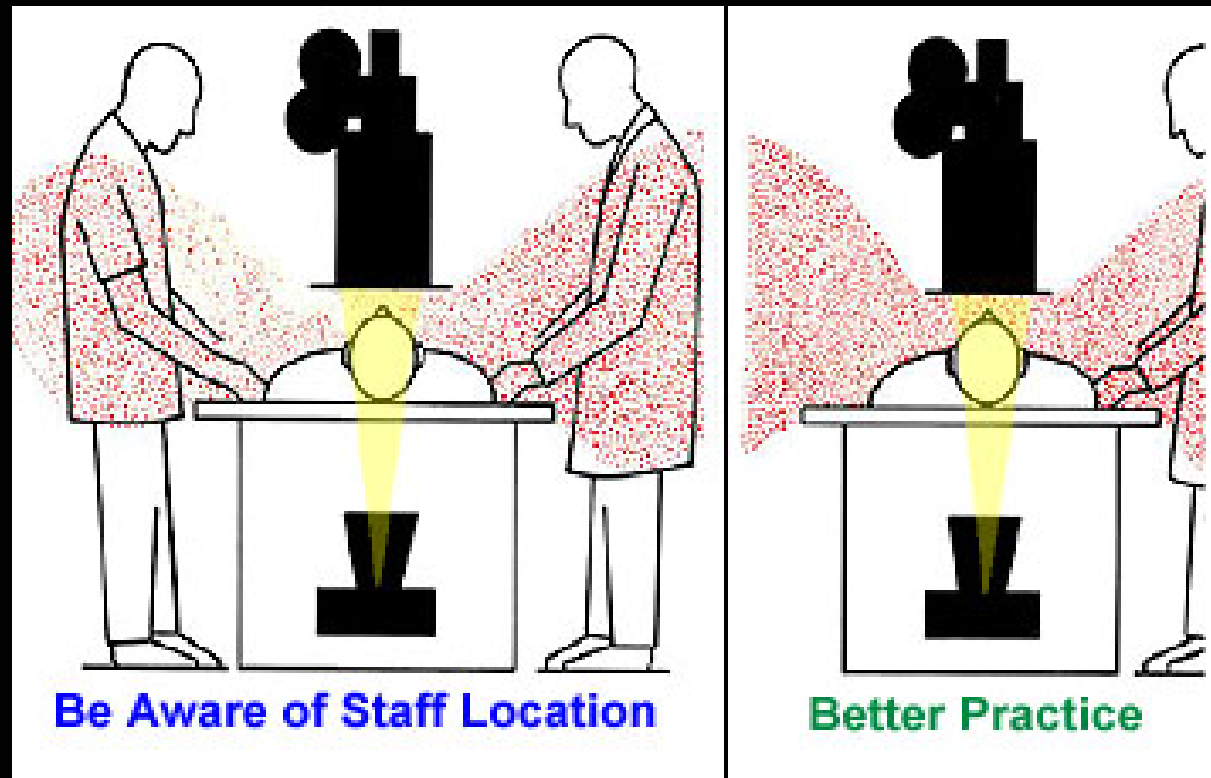
Vertical Dose Levels



Exposure and Staff Location

- Radiation levels are increased with staff standing close to the patient
- Levels are highest under the table as the patient provides a stop for the beam

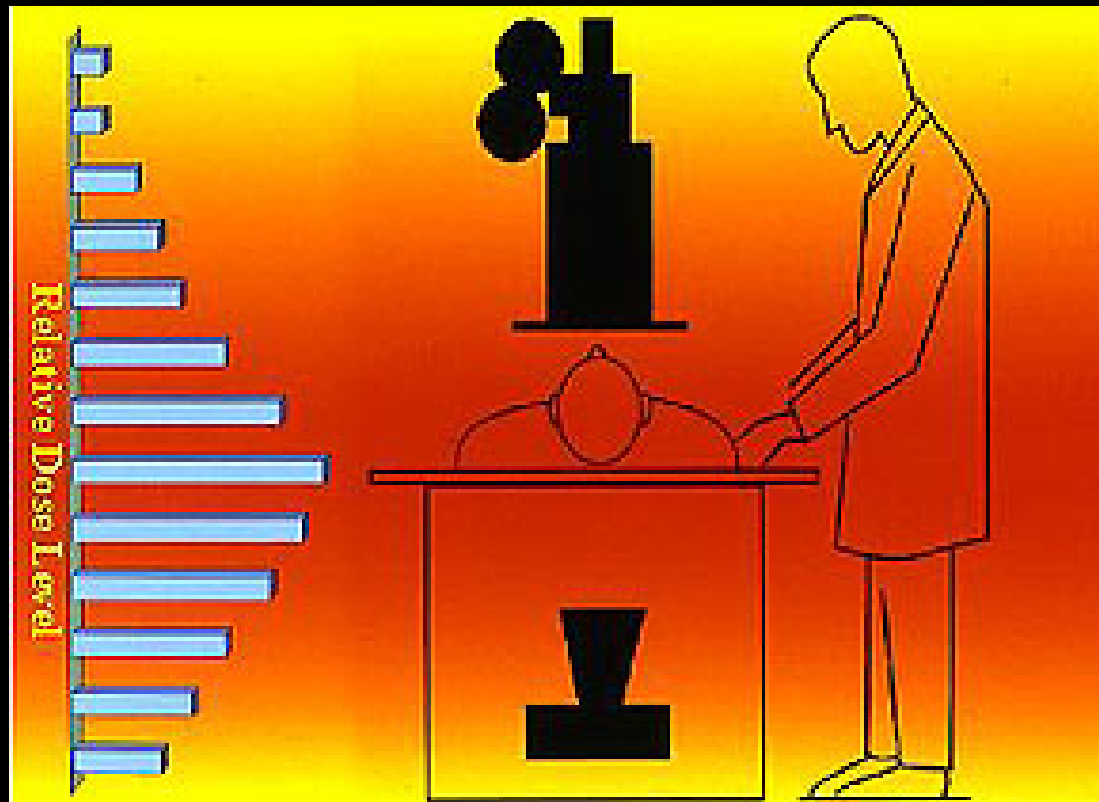
Distance is key!



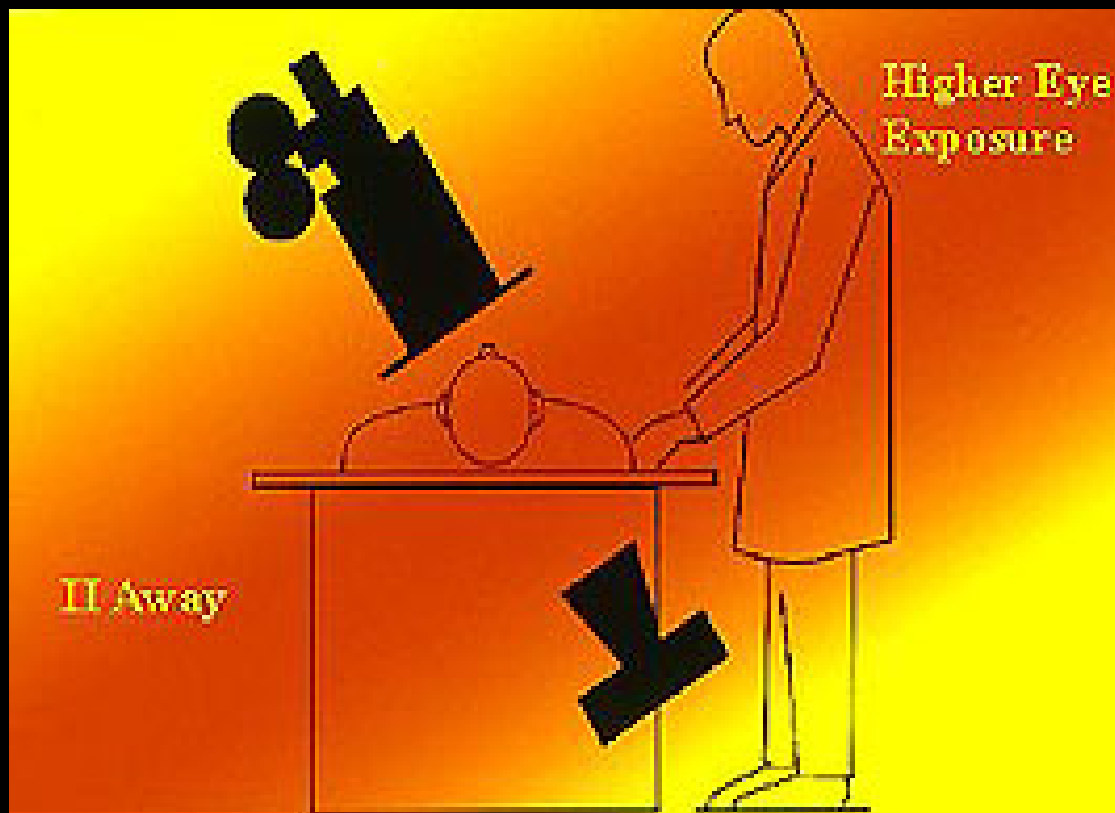
Effects of Tilt on Radiation exposure

- Scatter profile changes with c-arm position
- Oblique angles cause higher exposure to head and eyes when the tube is tilted toward from
- Exposure to the head and eyes is lowered when the tube is tilted away from you

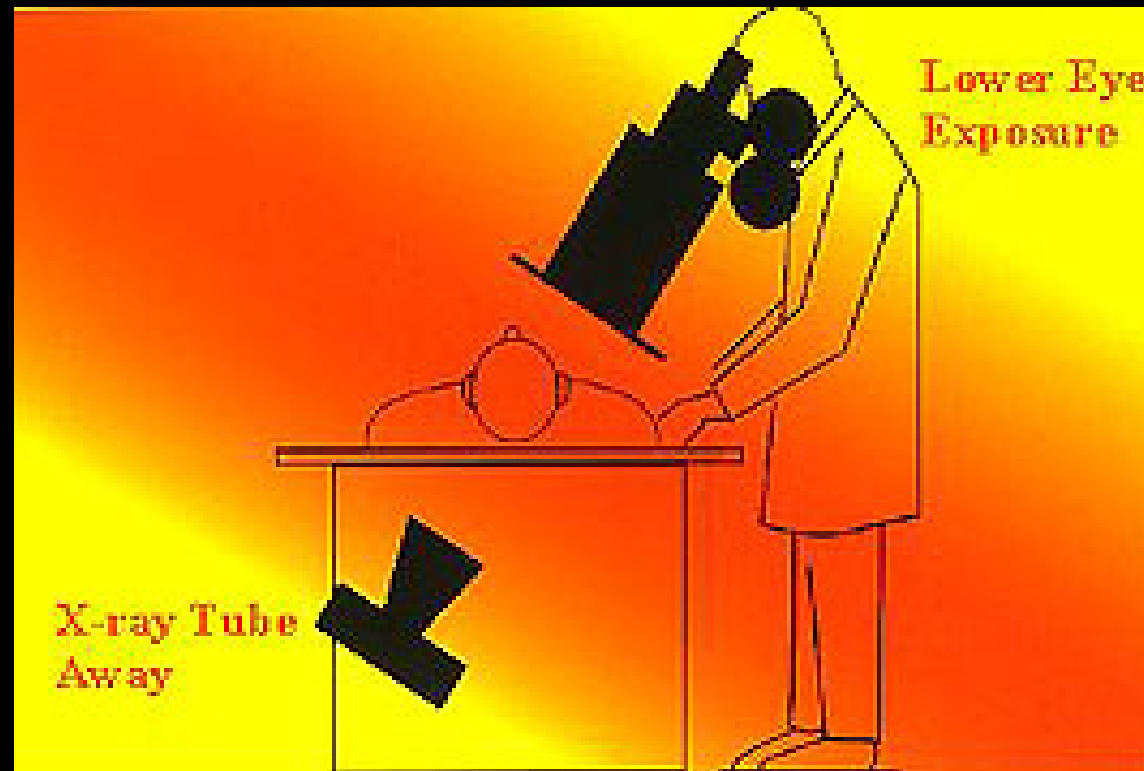
Vertical Dose Levels



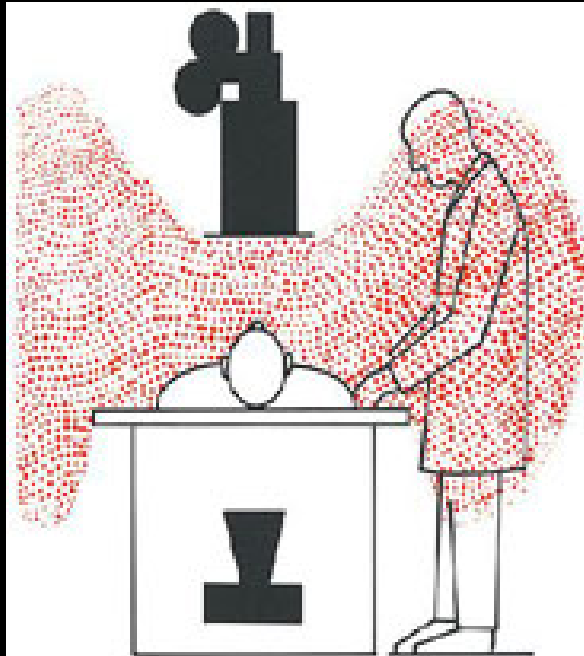
Intensifier away, tube toward



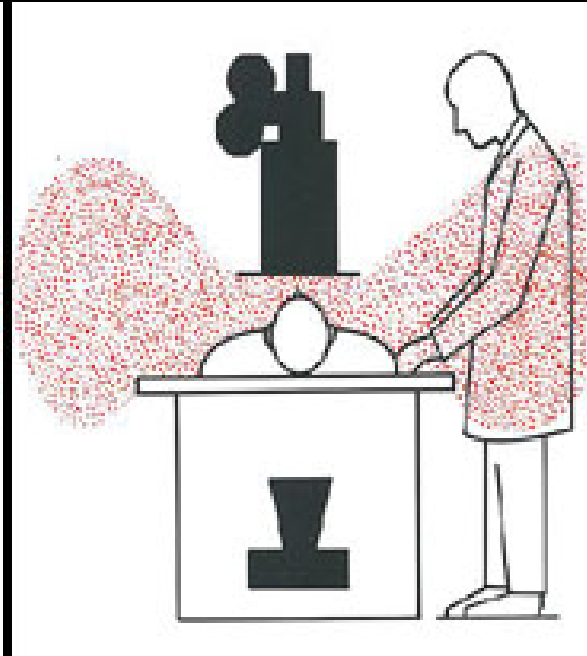
X-ray tube away, Intensifier toward



Air gap and scatter



**Enhanced Exposure
More Noise from Scatter**



Better Practice

Radiation shields

- Can reduce exposure more than 90% when placed as near to scatter source as possible
- Rolling shields, ceiling mounted, table side drapes

Radiation Exposure Protection

- Nothing provides total protection
- Check lead aprons for integrity
- Wrap around aprons are best
- About 90% reduction in radiation exposure
- Thyroid shields
- Clear lead glasses
- Lead gloves

Principles of Radiation Safety

- TIME exposed
- DISTANCE from source
- SHEILDING use

Time factor

- Exposure is directly proportional to unit activation
- No automatic timer
- Foot pedal or hand control depression determines the length of radiation exposure
- Record usage time
- 5 minute alarm

Brightness: ABC vs. manual control

- Manual control: exposure is not effected by patient size, image area or tissue type and can result in poor images
- Automatic brightness control: produces a consistent quality image but exposure changes with factors listed above

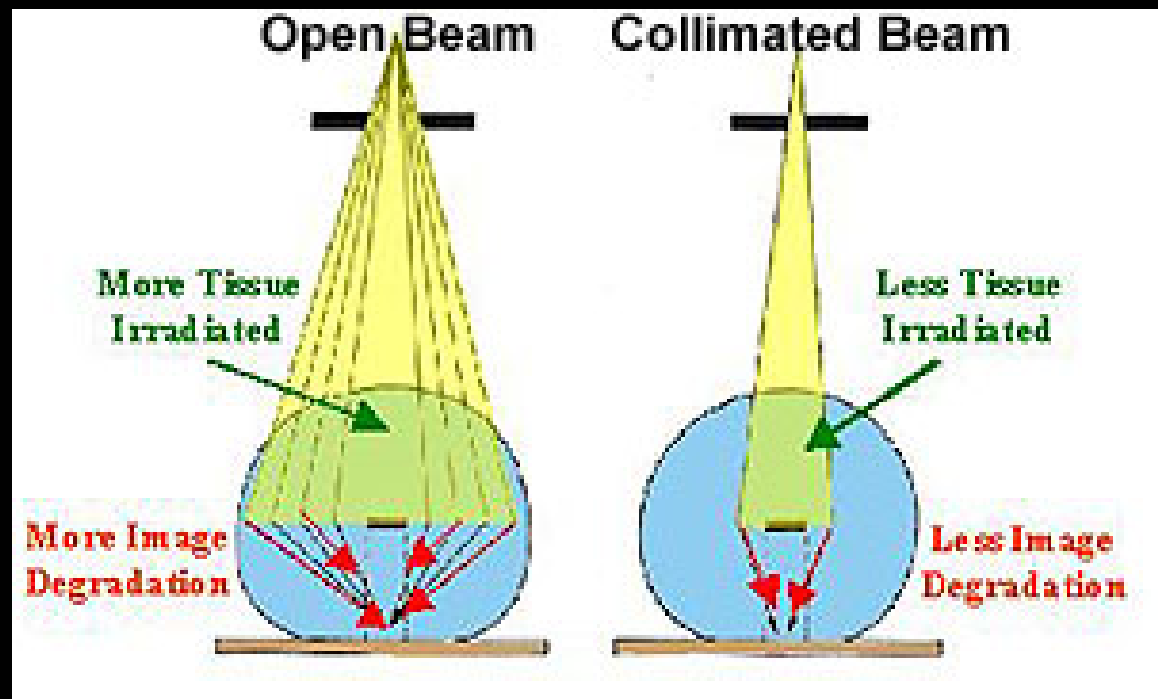
Imaging modes

- Normal ESE—average exposure rate of 2 R/min
- FDA limits routine fluoro use to 10 R/min
- “boost” mode can provide up ESE up to 20 R/min for brief duration

Field Size

- Area of x-ray beam use
- Can be reduced by collimation which shrinks the field thereby decreasing scatter and improving image quality
- Collimation reduces patient exposure

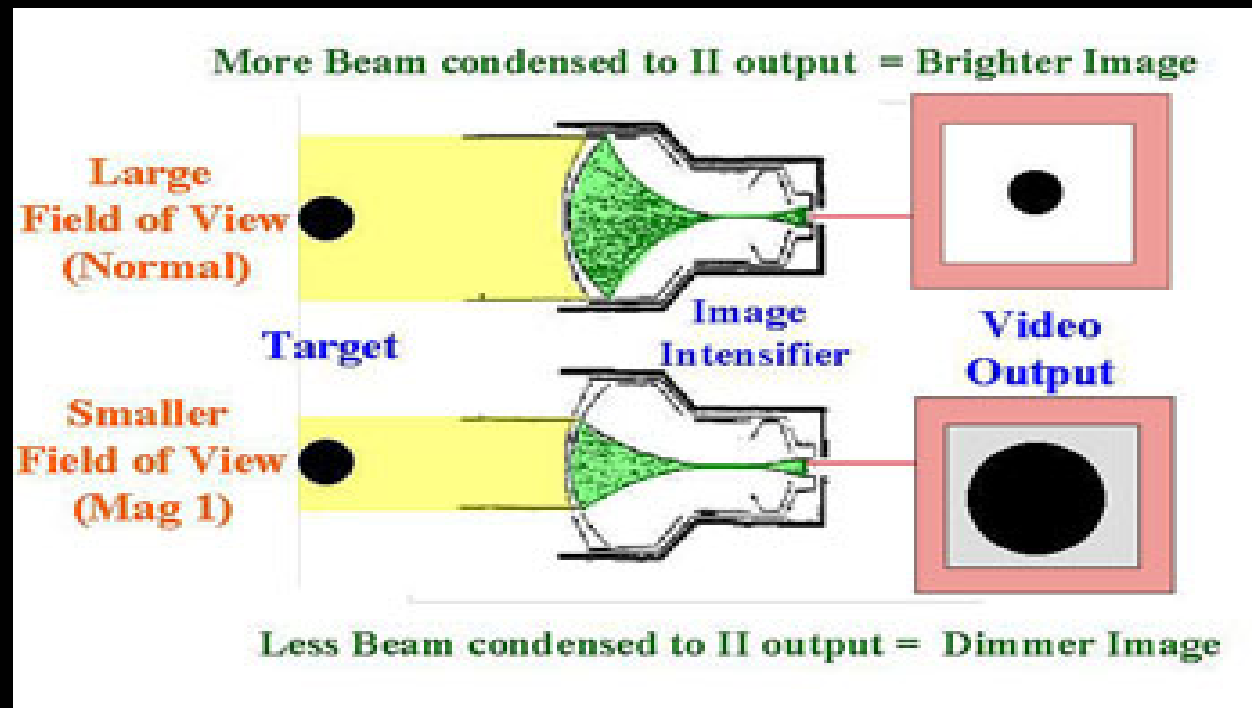
Effects of Collimation



Magnification Mode

- Increased magnification results in larger radiation and increases image brightness

Normal vs. Mag 1 mode



Last Image Hold

- Freeze frame – helps decrease exposure

Occupational dose limits

- Department of health regs
- US Nuclear Regulatory Commission-lens of eye dose limit of 15 rems per year
- Radiology Safety Officer

Definition

- 1 rem is 1000 mrem

Annual Radation limits

- Whole body – 5 REM
- Eye – 15 REM
- Skin and extremity – 50 REM
- Thyroid – 50 REM

Radiation safety studies

- 2002 study by Fishman et al reported .03 mREM with Lumbar ESI and proper technique, equipment and distance greater than one meter from patient

Radiation safety studies

- Botwin et al (2001, 2002) reported avg exposure for TF ESI in 100 procedures was 70 mREM ring, 40 mREM eye, 30 mREM outside the apron
- Caudal ESI – 2.44 mREM eye to 4.10 mREM hand

Procedures Requiring Fluoro

- Transforaminal injections
- Selective nerve root block
- SI joint injection
- Lumbar sympathetic block
- Celiac ganglion block
- Facet joint block
- Medial Nerve Branch Block
- Intervertebral disc injection
- Trigeminal block
- Neurolytic block
- RF neuroablation

Reported Average length of fluoro time per type of block- Botwin 2001-2

- Lumbar TF ESI 5-38 seconds (avg 15.6)
- Caudal ESI 2-33 seconds (avg 12.55)

Reported Average length of fluoro time per type of block- Paulson 2001

- SI joint avg 11 seconds -
- Cervical injections 18.4 seconds
- Lumbar ESI 17.6 seconds
- Overall average per block
7.7 +/- .021 seconds per procedure

Calculations of exposure

- 3000 procedures or 23,1000 seconds per procedure.
- Using 1.345 mREM outside apron and 0 inside = 4035 mREM outside
- Below 5 REM annual limit

Take Home Message

- Use intermittent fluoro
- Use image freeze hold
- Remember : 3 keys to reducing radiation exposure: Distance to source, length of radiation (beam-on time) and use of protective devices

Balloon Fiesta 2006



Balloon Fiesta 2006

