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Radiation Safety Training for Fluoroscopy Operators

Enduring Material: 3/1/2019 – 3/1/2020

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GAP: Documentation of required annual two hours of training in radiation safety/radiation protection for physicians who are not board-certifed in radiology but perform fluoroscopic procedures

PERFORMANCE EXPECTATIONS: At the conclusion of this program audience should be able to:

1. **Describe the principles and operation of fluoroscopic x-ray equipment**
2. **Describe the techniques of fluoro equipment operation used to minimize risks to patients, operators and personnel**
3. **Relate the radiation units and doses used in fluoroscopy with the associated biological risks**
4. **Describe additional radiation protection practices and devices used to reduce radiation risks to operators and personnel.**

Radiation Safety Training for Fluoroscopy Operators

Who Should Take This Course

Workers in Radiology and other departments where fluoroscopy equipment is routinely used and whose job duties require them to operate fluoroscopy units. Examples include:

- X-Ray Technologists
- Radiologists
- Licensed Practitioners operating within their scope of practice such as Urologists, Orthopedic surgeons, Neurosurgeons and Vascular surgeons (non-radiologist physicians who use fluoro)
- Residents and Fellows working under the direct supervision of a Radiologist or a Licensed Practitioner and operating within their scope of practice

Introduction

Fluoroscopy machines are used extensively throughout hospitals and outpatient facilities for guidance, intervention and diagnosis

Many departments beyond Radiology rely on fluoroscopy for reaching their clinical objectives: examples are Cardiology, Pain Medicine, Neurosurgery, Vascular Surgery, and others

In order to minimize the risk of fluoroscopy-induced patient injury, maintain radiation exposure to workers to a level that is as low as reasonably achievable, and ensure regulatory compliance, it is essential that consistent application of sound radiation safety practices is in place throughout the organization

This course satisfies the physician Radiation Safety/Radiation Protection training required in **105 Code of Massachusetts Regulations 120.405(K)** as well as the **Joint Commission Standard HR.01.05.03 (EP 15)** which requires annual training for individuals who use fluoroscopic equipment

Course Objectives

- Understand how to use personnel radiation monitoring devices and interpret dosimetry reports
- Identify the potential radiation hazards in fluoroscopy and how to minimize them
- Review the tools to reduce radiation dose to patients & keep worker dose as low as possible
- Know the red flags of patients at risk of skin injury
- Comply with annual radiation safety training requirements

Outline

Section 1: Radiation Safety Fundamentals

Section 2: The Radiation Environment in Fluoroscopy and How to Minimize Exposure to Patients and Workers

Section 3: Radiation Biology and Health Effects

Section 4: Practical Radiation Protection Techniques in Fluoroscopy

Section 1

Radiation Safety Fundamentals

Who Regulates or Provides Guidance for X-Ray?

	Agency:	What they do:
The Joint Commission	The Joint Commission (**TJC**)	New fluoroscopy standards effective January 2019. MS 5.14 describes physician privileges for fluoroscopy. Sentinel event if > 15 Gy from fluoroscopy
FDA	Food and Drug Administration (**FDA**)	Set equipment performance standards and safety with medical devices. Regulate fluoroscopy manufacturers. Adverse event reporting through MEDWATCH
AAPM American Association of Physicists in Medicine	American Association of Physicists in Medicine (**AAPM**)	Provide guidance on dose reduction and right-sizing techniques

Radiation Safety Oversight

- **Radiation Safety Officer (RSO)**:
  - Responsible for developing, implementing, and overseeing an effective radiation safety program
  - Ensure regulatory compliance
- **Radiation Safety Committee (RSC)**:
  - A representative from each department that uses radiation meets quarterly to review the program
- **Imaging Physicist**:
  - Tests x-ray equipment annually to confirm performance as designed and ensure image quality is optimized

Who Can Operate X-Ray Machines?

Your State agency should be consulted for specific regulations on operators but, most commonly, operators include the following:

1. Licensed Practitioners (LP) operating within their scope of practice
2. Radiology Assistants (RA) working within their scope of practice and under the direct supervision of a LP
3. An individual who has passed the ARRT fluoroscopy exam (or equivalent) and who is under the supervision of a LP
4. A medical resident or Radiology student under the personal supervision of a LP
5. A Radiation Therapist for OBI or port imaging only.

What is Meant by “Operation” ?

- Energizing the x-ray tube switch to produce x-rays

- Setting up a patient on the table with respect to the image receptor and x-ray tube (excluding clinical set-up)

- Determining the imaging technique to be used, frame rate, magnification mode, collimation etc.

Can we Detect Radiation with our Senses?

- The answer is “no”. We could be standing in a very high radiation field and not know it!
- We rely on special instruments to measure radiation and we use controls to prevent unintended exposure.
- X-Ray operators must understand the quantities and units used to express radiological terms

Units of Radiation

There are two systems of units used to describe radiation quantities. Operators must be able to convert between them.

1. Traditional units: the "R" units (Roentgen, rad, rem)

2. SI units: The International System of Units *"Système International"* (Coulomb/kg, Gray, Sievert)

Note: Just as one can say that 1 meter (m) = 1000 millimeters (mm), one can apply the same idea to any of the above listed units. For example: 1 Gray (Gy) = 1000 milliGray (mGy), 1 rem = 1000 mrem, 1 Roentgen (R) = 1000 milliRoentgen (mR), etc.

How to Convert from Traditional to SI Units

Quantity	Traditional Units	SI units	Conversion
Exposure	Roentgen (R)	C/kg	1 R = 2.58E^{-4} C/kg
Absorbed Dose	rad	Gray (Gy)	1 Gy = 100 rad
Dose Equivalent	rem	Sievert (Sv)	1 Sv = 100 rem

Important:

For X-rays in the body, 1 Roentgen is roughly equal to 1 rad, which is roughly equal to 1 rem

Quantities of Radiation

Common quantities used in fluoroscopy are:

- Exposure - the amount of ionization produced in air by photons. The units are roentgen (R) or coulombs per kilogram (C/kg)

- Absorbed dose - the amount of energy deposited in matter. The units are rad or gray (Gy or 1 J/kg)

- Dose equivalent - the absorbed dose, with a modifying factor that accounts for biological effectiveness of the radiation type. The units are rem or Sievert (Sv)

- KERMA is the transfer of energy from photons to charged particles, which then deposit their energy in the medium (Gy). “Air KERMA” is usually the metric reported on fluoroscopy systems

Quantities of Radiation

•DAP - Acronym for "Dose Area Product"

- An instrument near the collimator measures and integrates radiation exposure over the entire X-ray field of view (FOV)
- DAP is the product of dose (mGy) and x-ray beam area (cm^2) with the units mGy-cm^2. It displays at the console & screen.

•Cumulative Dose - This is the measured KERMA at the approximate point where the x-ray beam enters the patient. It displays (mGy) at the console & screen. Operators should observe this number throughout cases as a rough indicator of patient skin dose, especially during lengthy procedures.

Cumulative Dose

- The table shows the cumulative dose (Air KERMA) and total fluoro time for initial operator notification
- Additional notifications may be made as shown in the chart below
- This ensures the operator is aware that the patient dose is high and may be at risk of a skin injury

Parameter	First Notification	Subsequent Notifications
Peak Skin Dose	2000 mGy	500 mGy
Air Kerma	3000 mGy	3000 mGy
Fluoro Time	30 min	Every 30 min

Personnel Radiation Badges

- Required for fluoroscopy operators and support staff whose job duties require routine physical presence near the area of the x-ray field (typically within 6’ of a fluoro machine while in operation)

- Used to measure occupational, whole body radiation exposure

- If assigned, it is a condition of employment to use and return badges as instructed, not a personal choice

Radiation Badge (Dosimeter)

Badge Program Rules

- Always wear **OVER the lead apron** in the neck/collar area with the label facing the radiation source. The ideal location is the area of the whole body likely to get the highest dose.
- After working, store the badge on a badge rack or designated storage area. Do not leave them on lead aprons unless an apron is assigned to you and no one else wears it. Never take the badge out of the facility.
- Badges are exchanged monthly or quarterly.
- Old badges MUST be returned by the designated return due date.
- Do not wear your badge while undergoing personal x-ray exams such as chest or dental x-rays.

Badge Program Rules

- Only wear the badge with your name on it. Dosimetry records are *permanent legal documents*. This is also why it is extremely important to exchange your badges on time – badge readings are used to legally document your radiation dose history.

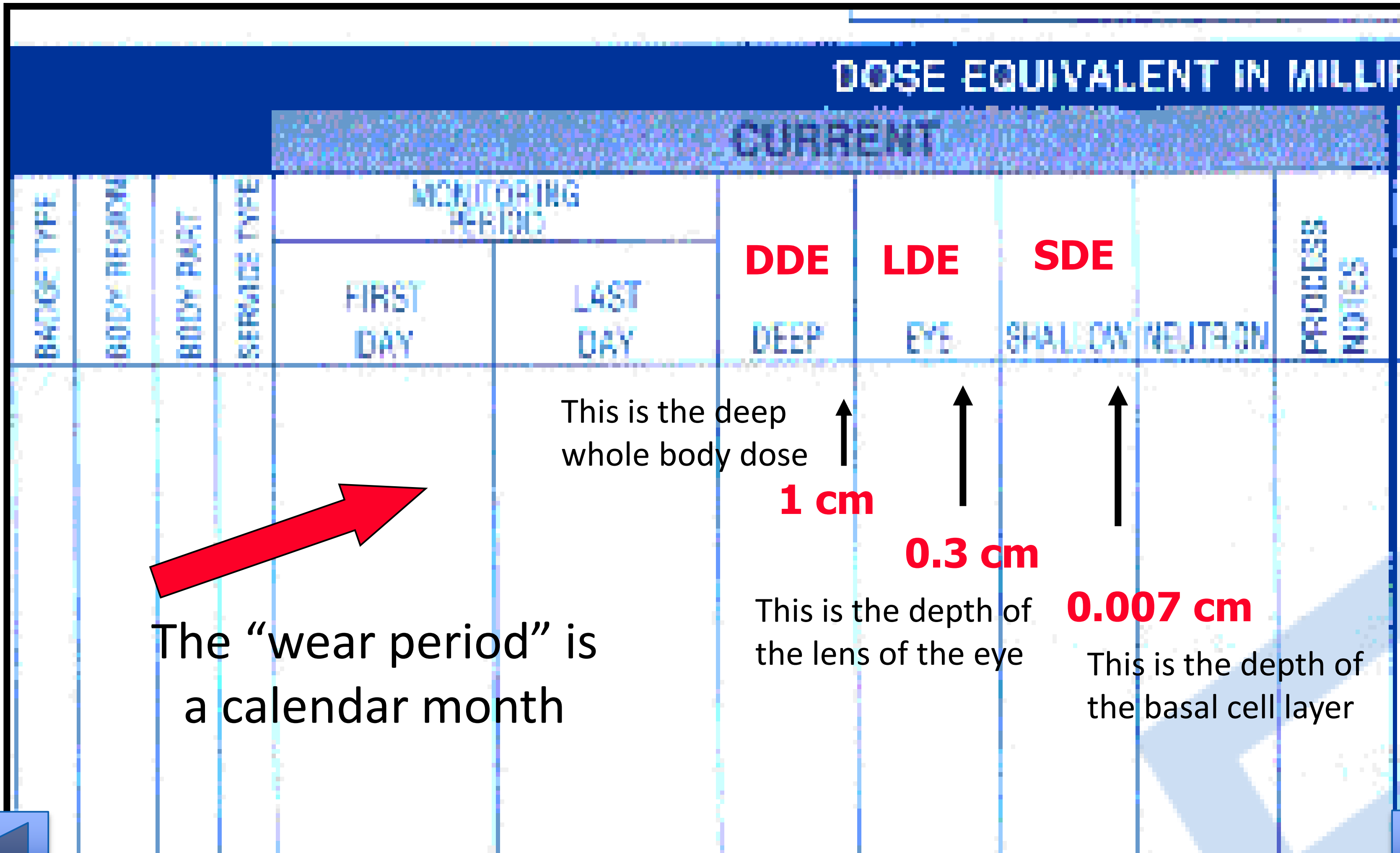
- Attempting to make your exposure appear lower by not wearing your badge, or wearing it in a way to minimize your exposure (such as under lead aprons), <u>is prohibited and is illegal</u>.

- If you moonlight at another job and a separate badge is issued (or if you work at different sites within a hospital system), you must inform the RSO or your direct supervisor to ensure that you are appropriately badged.

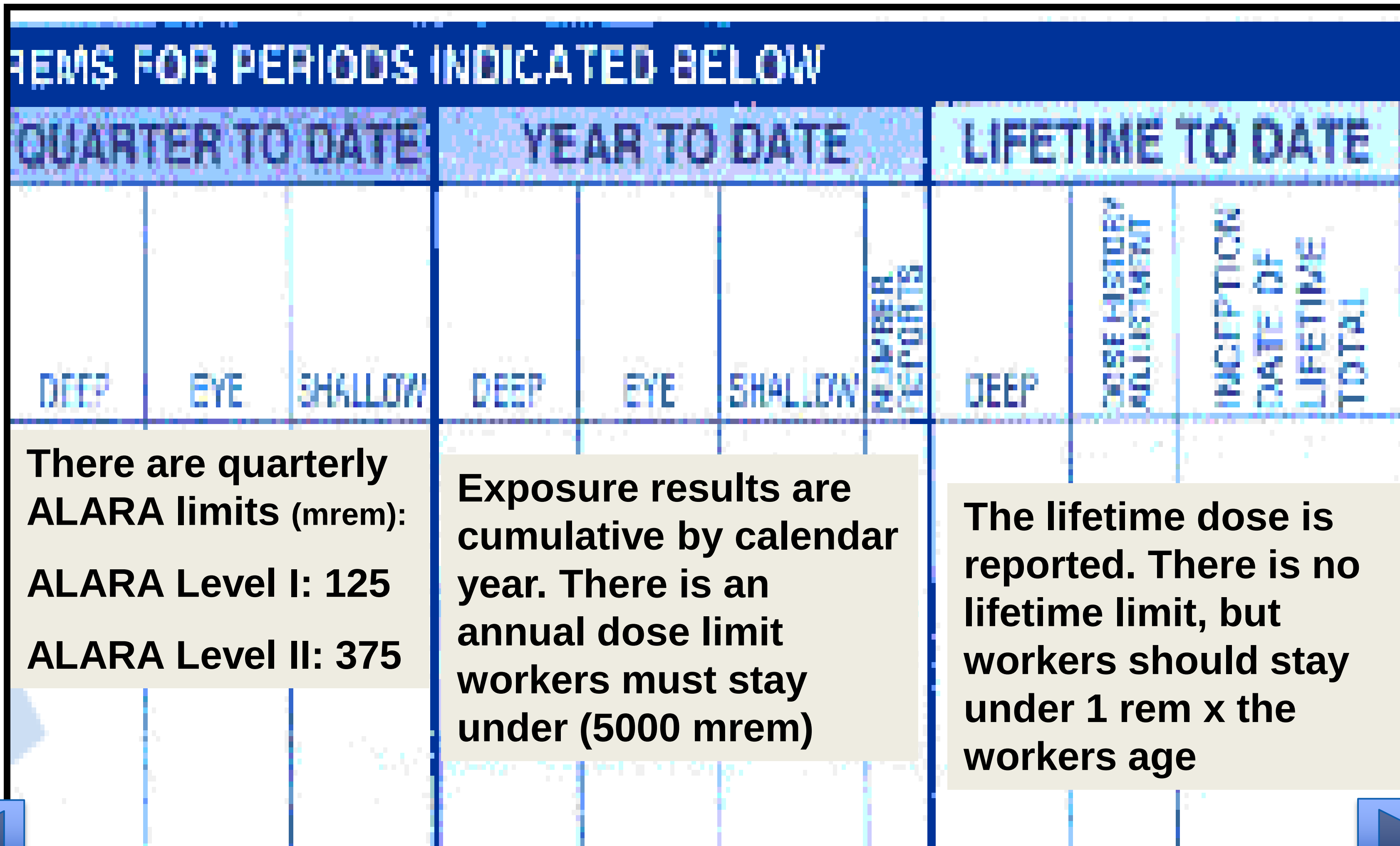
Radiation Exposure (Dosimetry) Reports

Everyone who wears a badge should promptly review their results.

Doses measured to the Whole Body (DDE), lens of the eye (LDE) and Skin (SDE) are reported for each wear period



Quarterly ALARA levels I and II are established. Annual and lifetime doses are also reported.



There are quarterly ALARA limits (mrem):

ALARA Level I: 125

ALARA Level II: 375

Exposure results are cumulative by calendar year. There is an annual dose limit workers must stay under (5000 mrem)

The lifetime dose is reported. There is no lifetime limit, but workers should stay under 1 rem x the workers age

ALARA Program

As Low As Reasonably Achievable

- To avoid ever reaching an annual limit, lower tolerances are set and are reviewed quarterly by the RSO
- Quarterly cumulative dose is tracked against ALARA level I (125 mrem) and Level II (375 mrem). These limits can be used as a starting point, but the facility can change them based on their needs.
  - Note: check with your facility's Radiation Safety Committee members regarding the set ALARA Levels that are specific to your facility. These may be different.
- Workers receiving > Level I and II are reported at RSC meetings
- Workers who receive > Level II receive an ALARA Memo from the RSO and additional inquiry into the reasons for the higher radiation doses. This requires a response from the radiation worker.

Annual Dose Limit

- This is the maximum amount of radiation below which adverse health effects have never been observed in the history of radiation use (over a century).

- Does not define a "safe" level. It is a risk-based limit. If a limit is exceeded, it does not mean a health effect will occur, but rather that risk increases.

Annual Dose Limits

These are highly conservative risk-based limits that attempt to identify a level of risk comparable to other safe industries.

Exposed area / individual	Traditional Units	International (SI) Units
Whole Body	5 rem / year	50 mSv / year
Lens of eye	15 rem / year	150 mSv / year
Other Organs	50 rem / year	500 mSv / year
Skin or Extremity	50 rem / year	500 mSv / year
Child/minor	10% of adult limits	10% of adult limits
Embryo/fetus	0.05 rem / month	0.5 mSv / month
General Public	0.1 rem / year	1 mSv / year

One-Badge EDE (Effective Dose Equivalent)

- Fluoroscopy workers who always wear a lead apron when working may be eligible for the EDE program.
- EDE uses a correction factor (30%) to reduce the over-apron collar dose to account for the lead apron protecting most of the whole body.
- The dosimetry report will list both the over-apron collar dose and the adjusted EDE dose, which becomes the legal dose of record.

Radiation Workers and Pregnancy

- The embryo/fetus has increased sensitivity to radiation and must be protected from unnecessary radiation exposure.
- The <u>most</u> sensitive phase includes gestational weeks 8 to 15
- Federal and State laws require that pregnant radiation workers have the option to voluntarily declare pregnancy in writing to the RSO. Only with this signed declaration may any changes be made to job duties. The intent of the law is to prevent discrimination of females in the workplace
- If a pregnant employee chooses <u>not</u> to declare the pregnancy, she must be treated as any other worker who is not pregnant.
- The worker may undeclare at any time and for any reason.

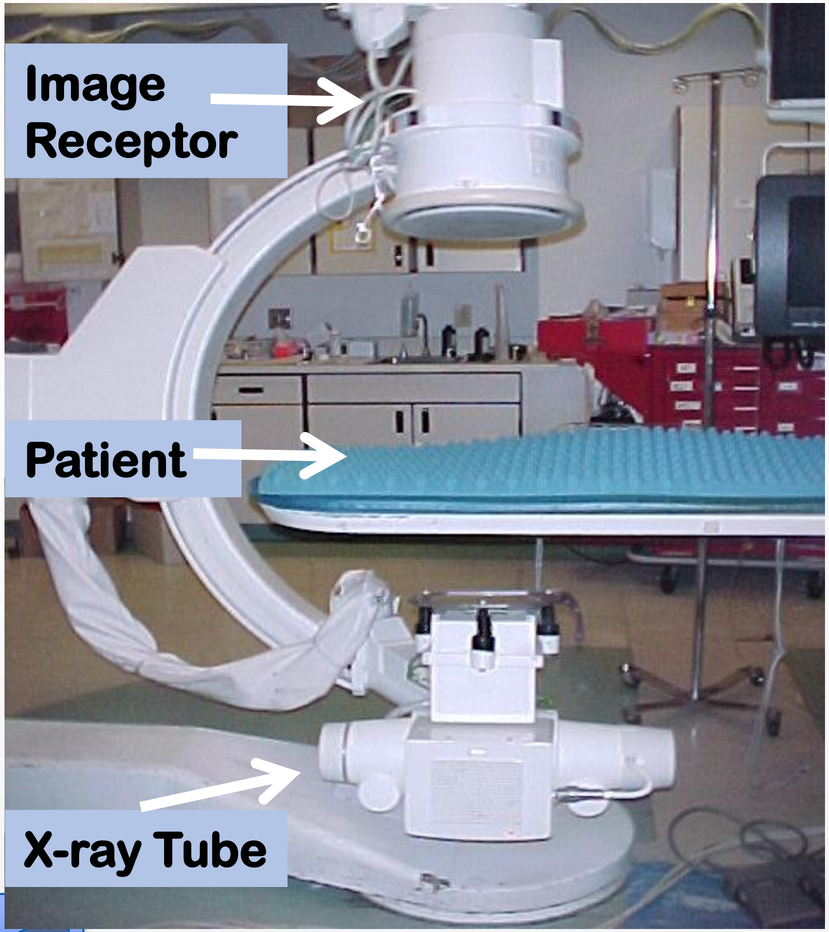
Radiation Workers and Pregnancy

- The following changes occur with a declared pregnancy:
  - Dose limits are reduced to 500 mrem for the gestation and 50 mrem/month
  - A monthly fetal monitor shall be issued and worn in the abdominal area underneath the lead
  - Any restriction to job duties identified in the "Pregnancy Policy for Radiation Workers" shall be followed
- In a fluoroscopy environment, the use of wrap-around lead aprons continues to be very effective at keeping dose well below the limits. In most cases, the pregnant worker can safely continue job duties without restriction.

Section 2

The Radiation Environment in Fluoroscopy and How to Minimize Exposure to Patients and Workers

This is a C-Arm



- The x-ray tube (shown underneath the table) is placed at the anatomy of interest
- The x-rays pass through the patient and hit the image receptor (shown above the table).
- The connecting arm looks like a "C" and can rotate all around the patient.

C-Arm Radiation Environment

1^0 useful beam:

- Emitted from the x-ray tube, passes through the patient, with a fraction reaching the receptor to form an image.
- Beam intensity limit is 10 R/min in normal mode and 20 R/min in boost mode.

2^0 beam:

- When the 1^0 beam hits the patient & table it scatters in all directions. This is what exposes workers.
- The intensity is 1/1000th the intensity of the 1^0 beam at 1 m.

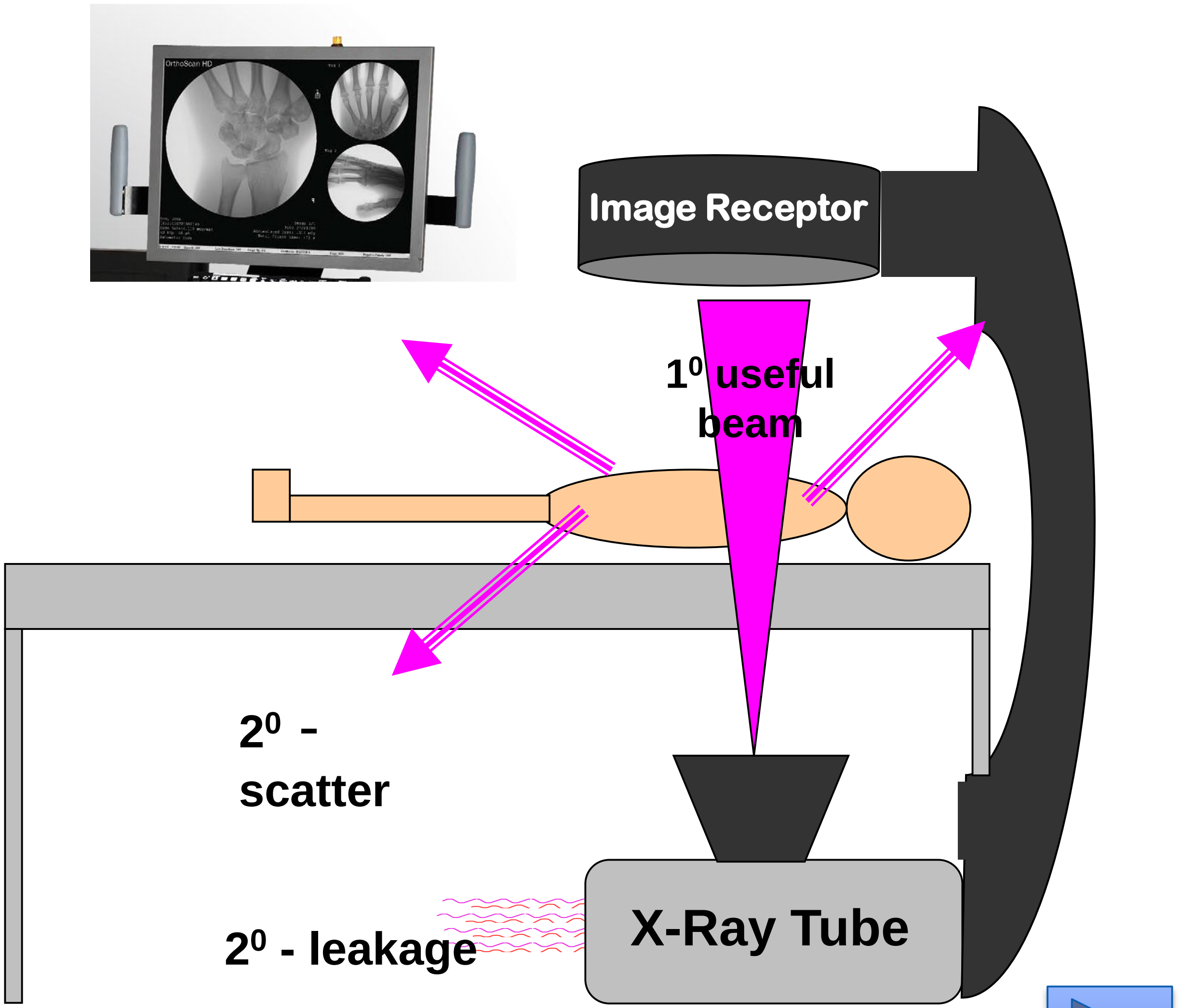
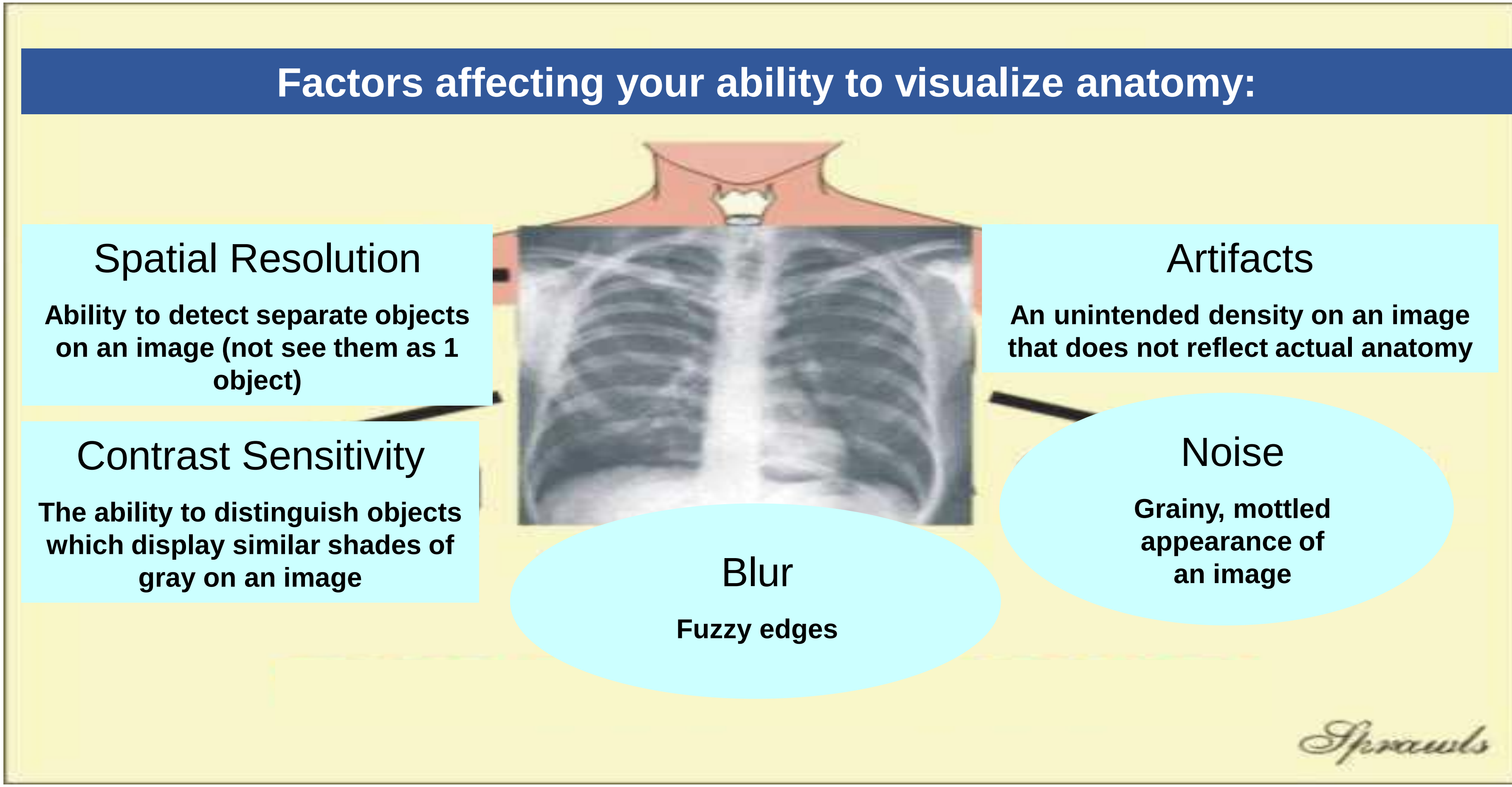


Image Quality – Differential Absorption

- Materials that make up our body (water, air, bone, fat, soft tissue) have varying atomic #'s, mass, and density
- X-rays passing through are not homogenously absorbed
- Air & fat are radiolucent (poor absorbers so x-rays pass through easier) so are black on image
- Bone appears white - good absorber; less transmission
- Everything in-between gives all the shades of gray

Factors that Affect Image Quality



Courtesy: http://sprawls.org/ppmi2/IMGCHAR/

The Dilemma

- Enhancing image quality and reducing dose are diametrically opposed
- Whatever we do to improve image quality increases radiation dose to patients and to workers & vice versa – this is the central tradeoff in radiation imaging
- The only answer is for the fluoroscopy operator to understand how to deliver the LOWEST possible radiation dose while getting the BEST possible image

X-ray Control Mechanisms

- **Beam Current (mA)**: Increasing the mA increases the number of photons & dose, but reduces the noise which improves image quality.

- **kVp:** Affects photon energy & increases beam penetration. Increasing the kVp is a good dose-sparing strategy for skin.
  - Use a lower kVp if the anatomy has poor subject contrast such as the breast. Use higher kVp if good subject contrast exists such as with the chest (lungs and ribs)

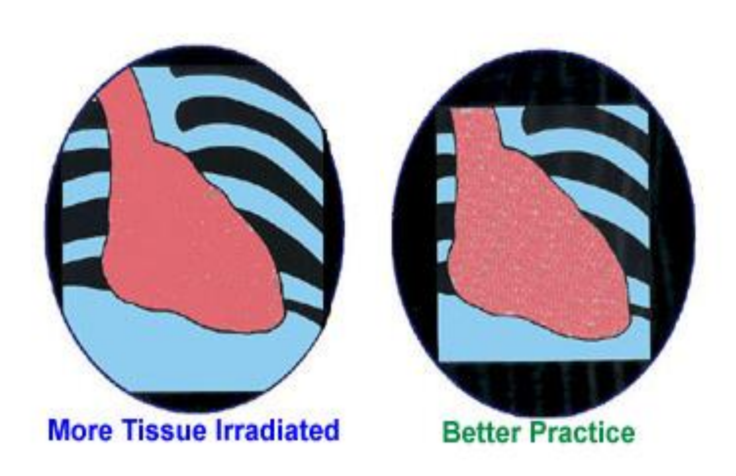
- **Automatic Brightness Control (ABC)**: a feedback loop that automatically adjusts kVp and/or mA to maintain constant image brightness regardless of the patient size or density of anatomy.

X-ray Control Mechanisms

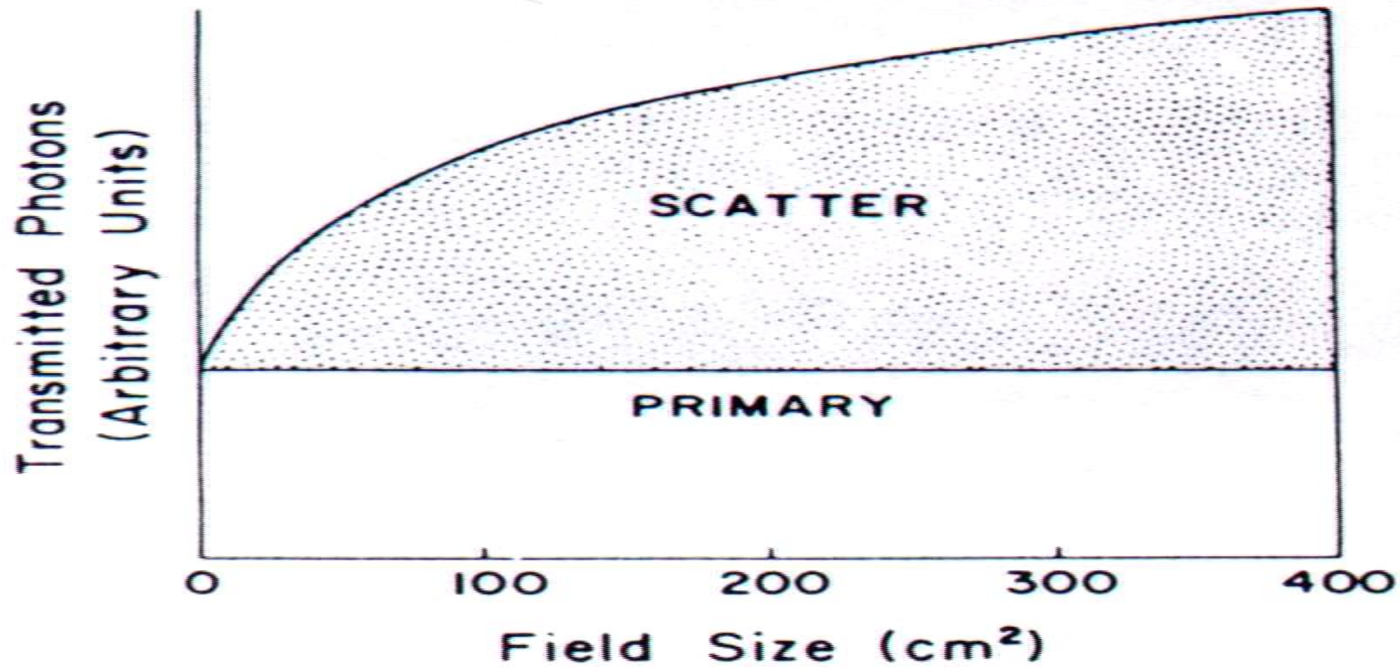
- **Exposure Time** increases the amount of time exposed to x-ray radiation and, thus, dose:

  - Pay attention to the 5 min timer and total fluoro time
  - Fluoro only when an interpreting clinician is viewing
  - Use high dose modes (Boost and MAG modes) sparingly. Only use when a low-noise image is critical

- **Collimator**: Reduce the beam size to capture only the anatomy of interest. This will reduce scatter, improve image quality, and have less overlapping fields.



The Effect of Collimation on Scatter and Primary Beam is Shown Here and Illustrates Why Coning Down is Best! Smaller field sizes result in less scatter radiation, which means less radiation dose for you and the patient!

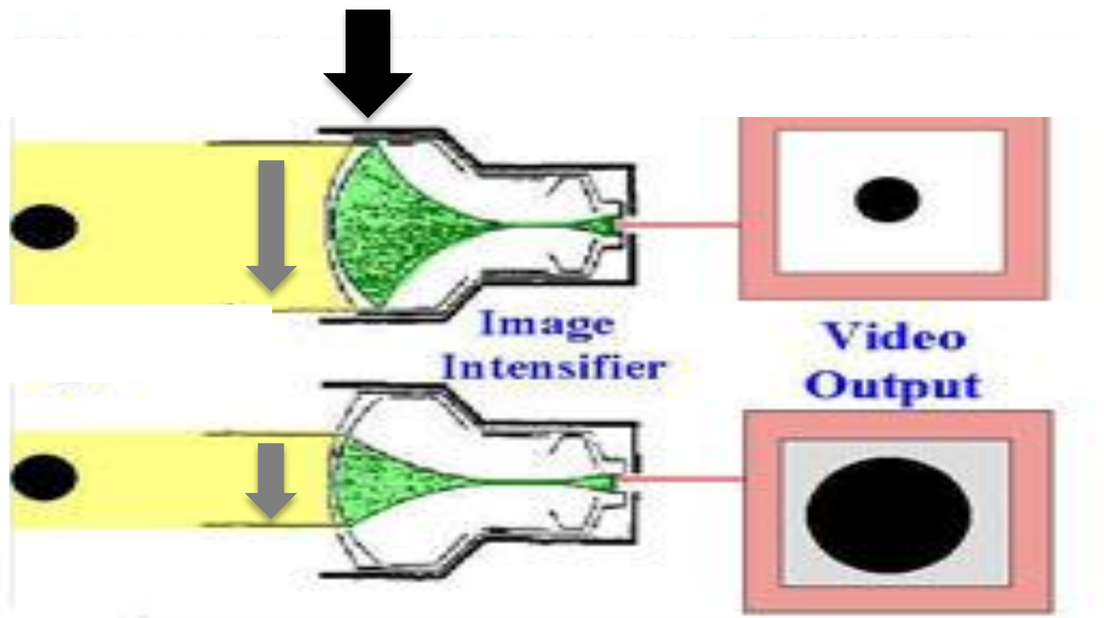


Magnification (MAG) Modes

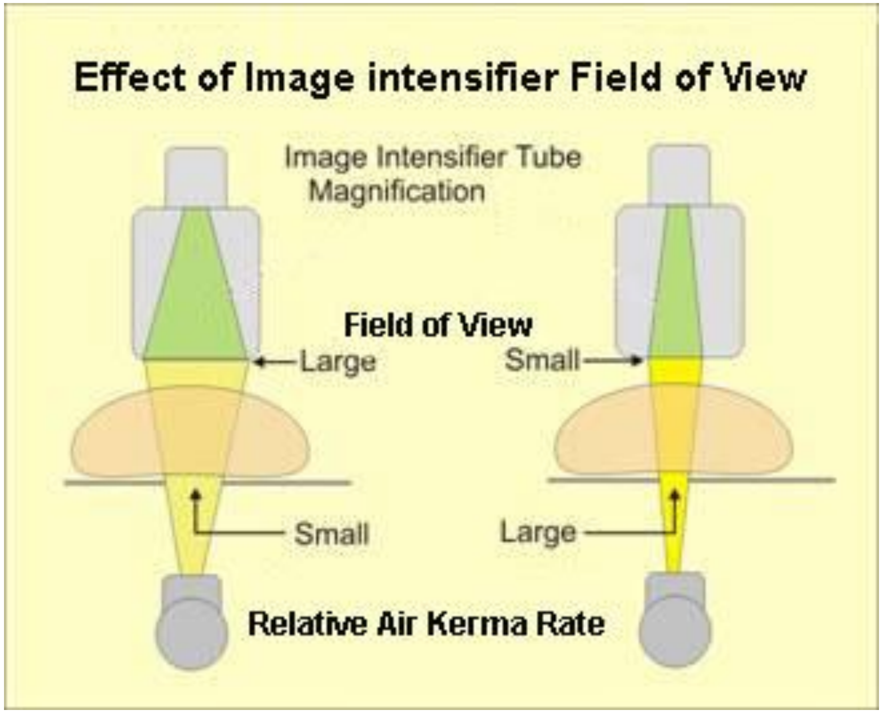
- **MAG modes** use smaller fields of view (**FOV**s of less than 9 inches typically) to expand the image on the monitor. Resolution increases while distortion decreases to see smaller detail. Fewer x-ray photons are used, the ABC increases to compensate, and patient dose is higher.

Normal mode FOV is large

MAG mode FOV is small



FOV = field of view, which is the size of the x-ray field on the image intensifier

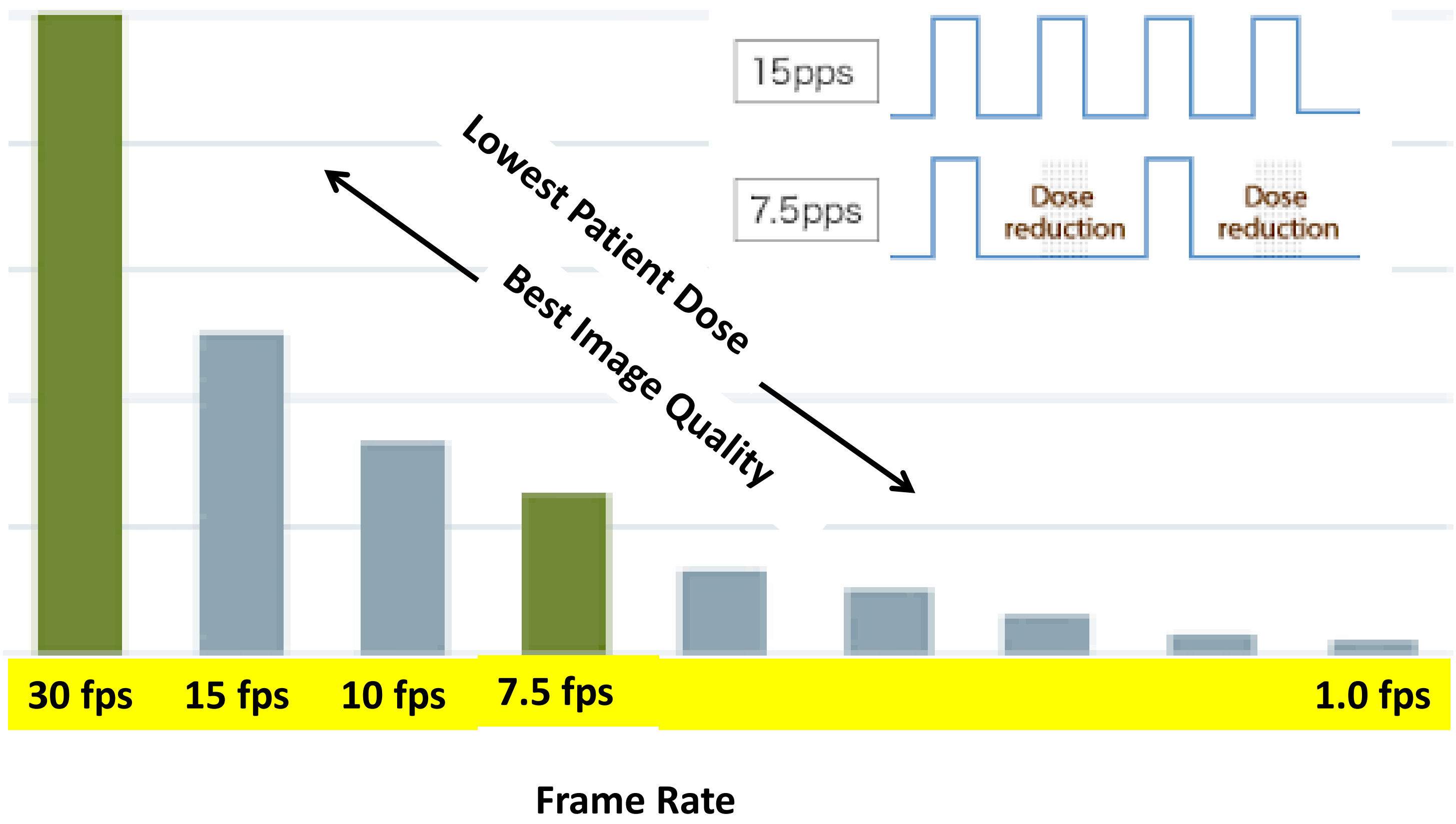


FOV:	DOSE RATE (mGy/sec):
25 cm	0.3
17 cm	0.6
12 cm	1.3

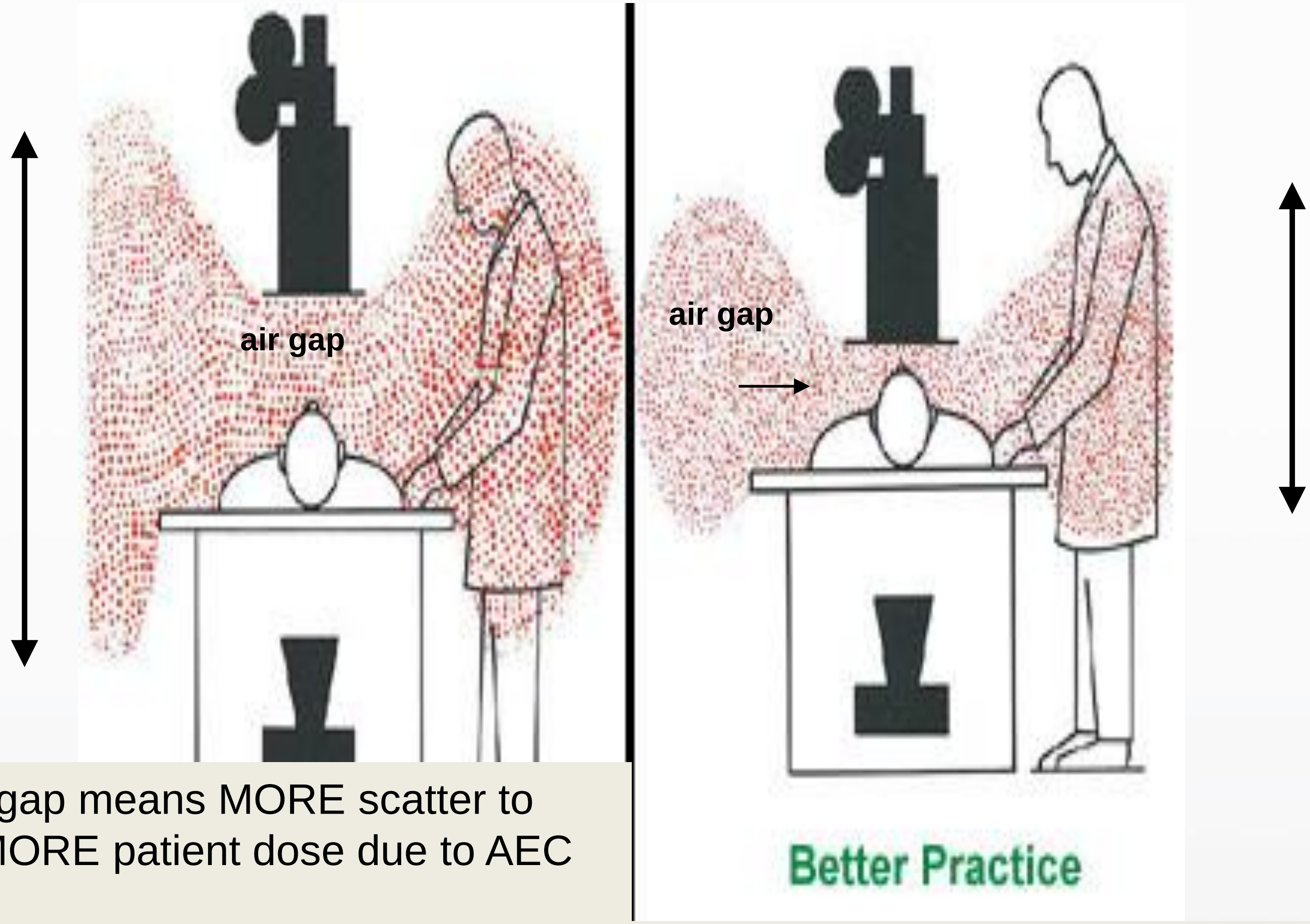
Changing from a large FOV (normal) to MAG mode (small FOV) increases the exposure needed by the ii, increasing patient dose.

Decreasing the FOV by a factor of 2 increases the dose rate by a factor of 4 with image intensifiers and by a different factor with flat panel detectors. Attention must be paid to magnification.

Using pulsed fluoro instead of continuous reduces dose but can decrease temporal resolution. Select the lowest frame rate for the needed temporal resolution.



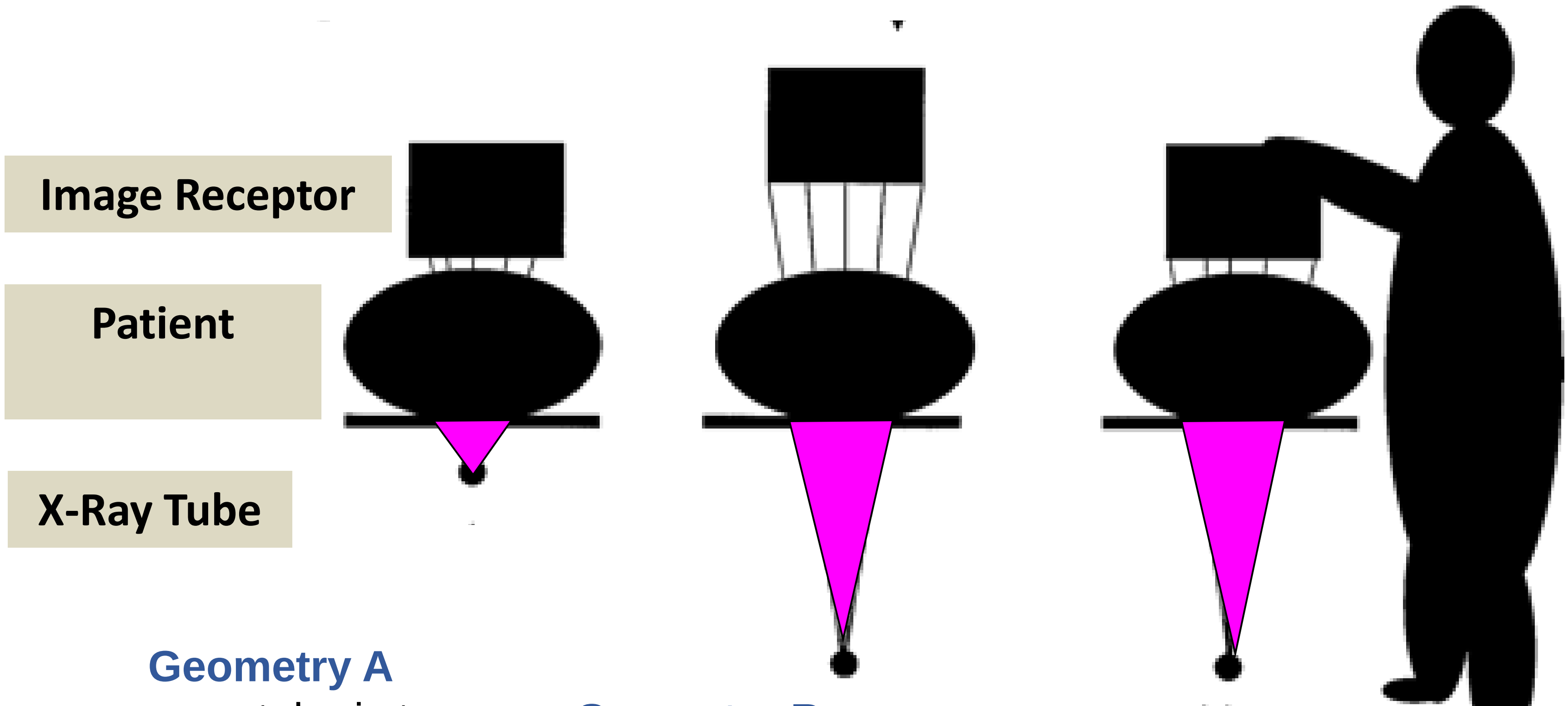
Air Gap is the Distance Between the Patient and Image Receptor – Keep it Small



Larger air gap means MORE scatter to operator & MORE patient dose due to AEC

Smaller air gap means LESS scatter to operator & LESS patient dose due to AEC

Patient Setup Relative to Tube & Receptor

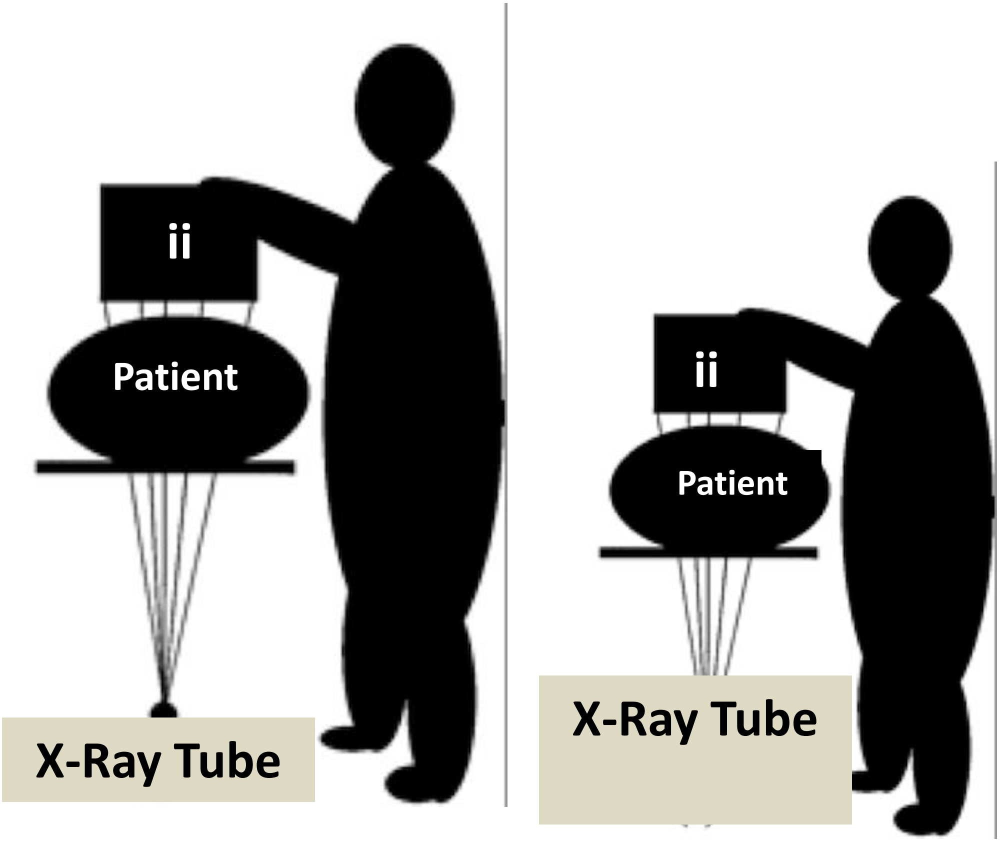


Geometry A
x-ray tube is too close to patient

Geometry B
x-ray tube OK; image receptor is too far away (AEC increases)

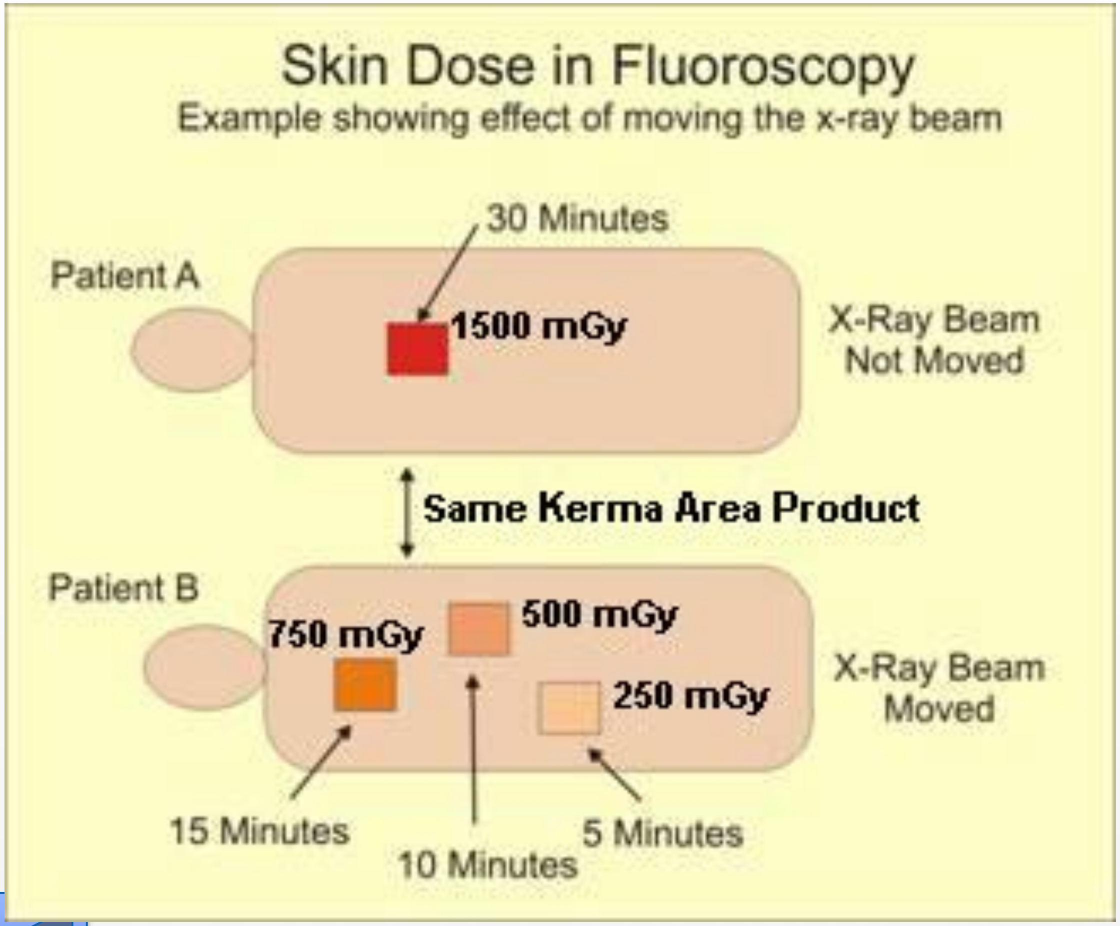
Geometry C is just right
The x-ray tube is further away and the receptor close to the patient

Working Heights



- Lowering the table to accommodate working height for operators of shorter stature moves the patient skin closer to the tube and dramatically increases dose
- Instead of bringing the table closer to the x-ray tube, try using a step stool to help keep doses lower

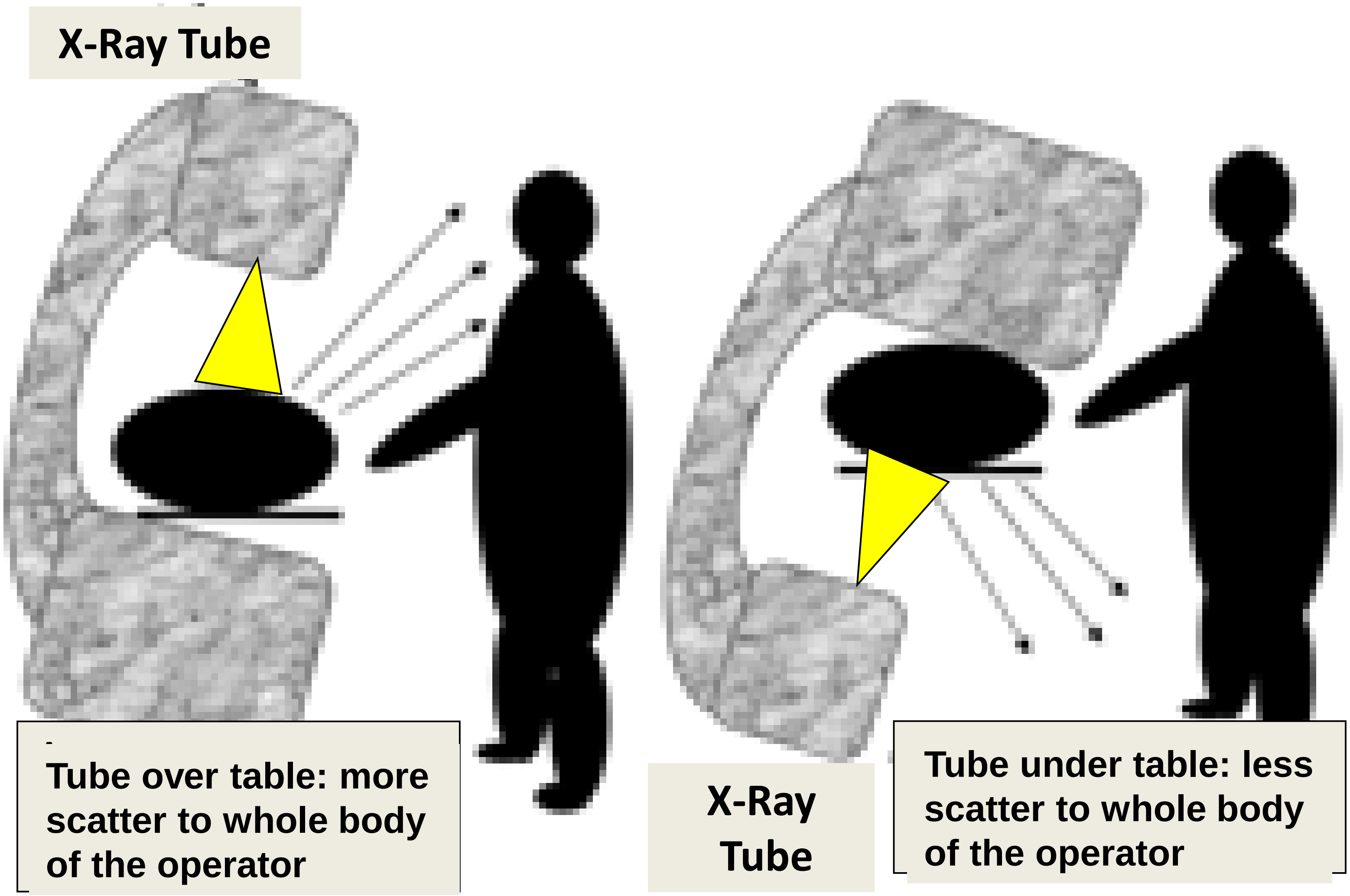
Effect of Changing Gantry Angles



Alternating the gantry angle in lengthy cases allows the total dose to be split to different patches of skin, reducing the risk of injury

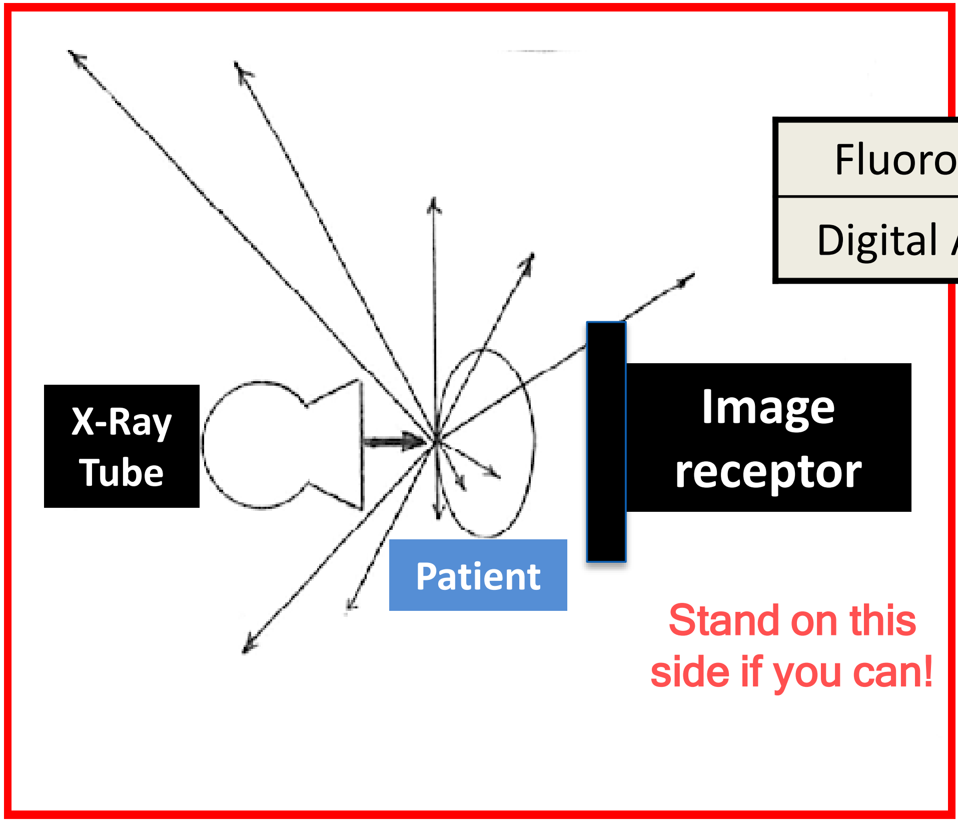
Try to **AVOID** overlapping fields and oblique, steep angles that puts the tube closer to skin.

AP versus PA Orientation



Laterals

When working in cross-table lateral configurations, **stand on the image receptor side**, NOT the x-ray tube side. The arrows in the picture show how scatter x-rays dominate in both quantity and strength on the tube side (numerically shown in the table). This may seem counterintuitive, but it is a measurable truth—the patient is the primary source of scatter, and x-rays tend to scatter back towards the x-ray tube from the patient!



	Receptor Side	Tube Side
Fluoro mode	5.5	22.5
Digital Acquire	254	1106

Summary of Factors that **Increase** Patient Dose
Red Flags for Potential Skin Injury

- Very obese patients and/or dense anatomy in beam
- Excessive use of MAG and BOOST modes
- High fluoroscopy time (> 30 min)
- Lots of runs, digital acquisitions, cine frames, etc.
- Using continuous (30 fps) vs pulsed (7.5 fps) fluoro
- Unchanging gantry angle exposing the same patch of skin throughout a study
- Wide open collimation instead of coning down

Summary of Factors that **Increase** Patient Dose
Red Flags for Potential Skin Injury

- Use of steep beam angles (puts the beam closer to skin)
- Large air gap between patient & image receptor
- Allowing skin to be closer than 30 cm from the tube (such as lowering the table for short stature physicians)
- Dose metrics that exceed the values below. Assign someone to monitor these & notify the operator when reached.

Parameter	First Notification	Subsequent Notifications
Air Kerma	2000 mGy	2000 mGy
Fluoro Time	30 min	30 min
P_{KA}	300 Gy·cm² *	100 Gy·cm² *

Reporting Responsibilities

The attending physician is responsible to report "high dose fluoroscopy events" for investigation following completion of an exam.

- This is typically defined as reaching or exceeding 5 Gy cumulative air kerma as displayed on the monitor or exceeding 45-60 minutes of fluoroscopy time in a single case
- In **Massachusetts**, any case that exceeds **2 Gy cumulative air kerma** must be documented in the patient's medical record and reviewed by the Radiation Safety Committee
- Reporting is to the RSO, Medical Imaging Physicist, or Health Physicist

Reporting Responsibilities

The attending provider physician is responsible to discuss possible side effects with the patient.

The area of anatomy where the effect would manifest must be identified, and the patient told to do a self exam every week until instructed to stop (depending upon the skin dose).

The patient should be instructed to contact the provider if an effect is observed.

The patient should be instructed to return for assessment if a skin effect is observed.

How should information be transferred to the patient's medical record?

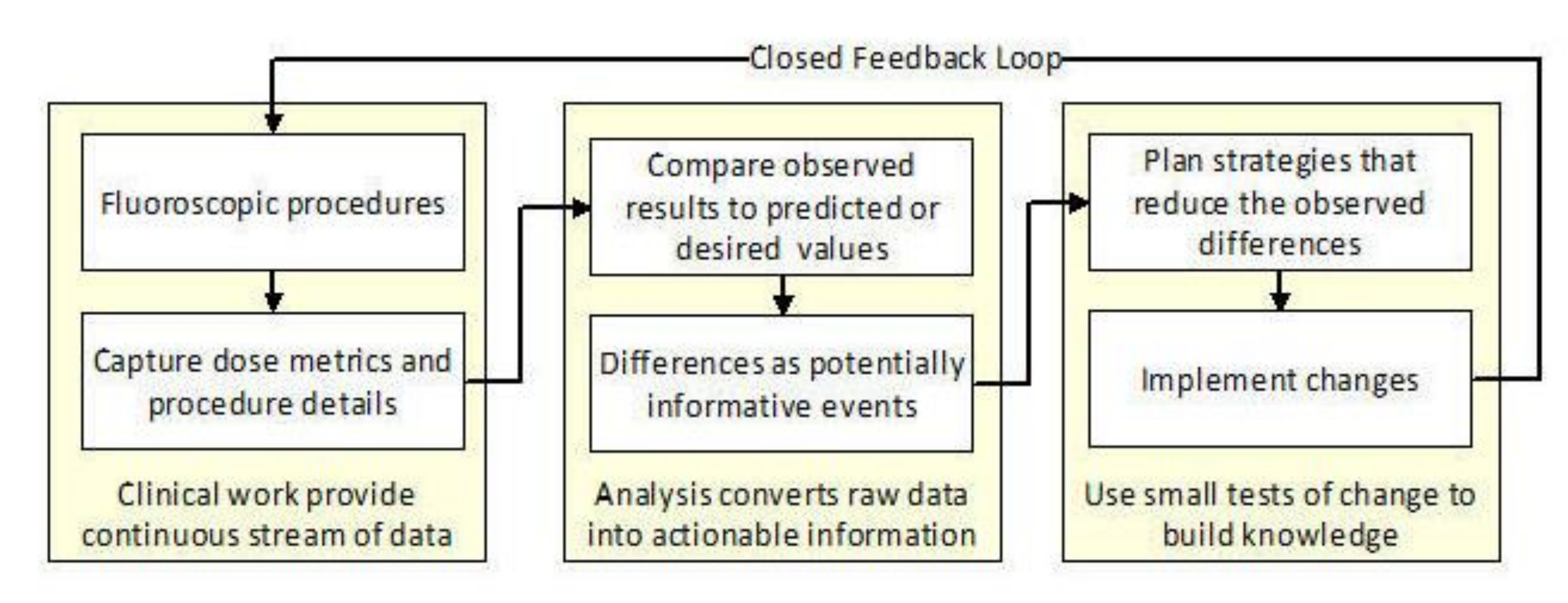
Displayed values are estimates and should be recorded as follows (examples below suggested by Image Gently information):

- Air kerma = 7.1 mGy (1 decimal place)
- KAP or DAP = 102 µGy*m^2 (rounded whole number)
- Fluoroscopy time = 2.2 min (1 decimal place)

Dose corrections based as a function of pediatric patient size?

- KAP does not need an additional correction as a function of patient size.
- The displayed KAP value is independent of the SSD, which is affected by patient size.
- Displayed air kerma does not need correction when using a general fluoroscopic table.
- Displayed air kerma does need correction when using a C-arm unit.
- Technologists should consult with their Qualified Medical Physicist to obtain correction factors for their C-arm units.

Capture and Analysis of Radiation Metrics From Fluoroscopic Procedures



This figure is from the Image Wisely website.

WEST PHYSICS®

Image Wisely: Pre-Procedure (READ-DO) Checklist

1. Elicit prior radiation exposure (including radiation therapy) and time-course. Examine the area to be irradiated, specifically searching for injury from radiation, surgery and infection.
2. For cases in which high radiation exposure is expected, informed consent should include discussion of radiation risk.
3. Use ultrasound, if possible.
4. Operator(s) and staff wear appropriate radiation protection: lead aprons (0.5 mm Pb equivalent front and 0.25 mm on sides and back), thyroid collars and glasses
5. Room personnel wear radiation dosimeters on collar outside apron and front of torso underneath apron.
6. Patient and equipment positioned to maximize use of hanging lead shield and lead table skirt. A rolling shield should be used when the table skirt cannot be situated to protect the operator (e.g., head of the table).
7. Appropriate anatomical program set for the desired study. Many fluoroscopy units allow different **imaging protocols**, which vary factors such as pulse and frame rates, filtration, and set point for the automatic exposure control unit. Lowest feasible pulse rate set for proposed study.
8. If patient is pregnant, informed consent should include an in-depth discussion of the risks versus benefits of the procedure. A medical or health physicist may be necessary. Collimate the X-ray beam to avoid direct exposure to the fetus.

Image Wisely: Intra-Procedure (DO-CONFIRM) Checklist

1. Keep the X-ray beam collimated to avoid unnecessary radiation exposure (especially radiosensitive organs, such as breast, thyroid, eyes and gonads)
2. Last Image Hold or Fluoroscopy Store functions are used whenever possible. If exposures are necessary, use lowest magnification, frame rate and collimate to the area of interest.
3. Source-to-object distance is as large as possible, while maintaining a comfortable table-working height for the operator. When tube is in lateral angulation, operator should place himself/herself next to the image receptor.
4. Image intensifier is as close as possible to the patient to reduce radiation scatter, except when deliberately using air gap technique for geometric magnification.
5. If X-ray beam angulations are necessary, minimize the path length through the patient. When using lateral projections, ensure patient's arms are out of the beam.
6. Overlap in field of view is minimized when performing exposures of large areas (e.g., lower extremity run-off arteriogram).
7. If hand injecting, extension tubing is available to move the operator away from the X-ray source. Use power injector whenever possible.
8. **Communicate with the team** about field of view, magnification, frame rate, contrast dose, length of run and suspension of respiration to avoid unnecessary/non-diagnostic imaging.
9. All unnecessary personnel should be behind protective screens or outside the room during image acquisition. Remind room personnel of the inverse square law (i.e., exposure at 6 feet is 2.8 percent of someone standing at 1 foot from the X-ray source).
10. If **substantial radiation dose levels (SDRL)** are exceeded, consider reducing radiation exposure or postponing completion of the procedure, as clinically appropriate.

Image Wisely: Post-Procedure (READ-DO) Checklist

1. Review and record patient dose metrics (e.g., stored in PACS as an image or radiation dose structured report).

2. If **dose metric exceeds thresholds**, the patient should be advised of the radiation dose, possible effects and instructed on appropriate follow-up.

Image Gently: Technologist Check-off list for fluoro examinations (Pause & Pulse)

Acquiring an optimal pediatric fluoro exam with minimal radiation dose to the patients must be a coordinated effort between the radiologist and the technologist. With the primary focus on patient's safety, comfort and the desired outcomes, the following should be considered:

- Know your patient. Become familiar with the basic ages and stages of child development in order to anticipate how the patient will react to the situation.
- Talk with parents and patients before the exam about reactions to previous imaging reactions and to new social situations. Find out if your patient has special needs or limitations that might affect the exam. Use the information to prepare the room and to prepare yourself.
- Present information in age appropriate language. Most toddlers are encouraged by talking about what is happening at the moment. Pre-school and young children need to know what is going to happen before it happens. Find out what works for your patient.

Image Gently: Technologist Check-off list for fluoro examinations (Pause & Pulse)

- Know your equipment. Be familiar with the availability of pulse fluoro. Know the exposure rate of your equipment in all modes of operation, with and without filtration.

- Share your technical knowledge with the imaging team. Protect your pediatric patient from excessive radiation dose by challenging the use of adult fluoro protocols in the department. Advocate for the use of alternative imaging when appropriate for the desired outcome. Keep track of fluoro times for all pediatric studies and work together to reduce those times.

- Prepare for the exam. Have all supplies, and extras, in the room and within arms reach. Suction supplies must be available for oral contrast studies. Monitors and oxygen supplies must be available for studies requiring sedation. Equipment and devices must be appropriate pediatric size.

Image Gently: Technologist Check-off list for fluoro examinations (Pause & Pulse)

- Provide radiation protection. Aprons, thyroid shield, and leaded glasses should be available for all personnel. Aprons should be provided to parents who are in the room during imaging. If possible, cover the head and foot of the table with flexible lead pieced to protect personnel required to be in close proximity of the patient.

- Keep you patient covered as much as possible for the exam. Young patients have modesty and feel vulnerable when exposed. Show them you understand. Core temperature is critical in neonates and must be maintained.

- Maintain constant verbal communication with your pediatric patient. Use soothing tones and sounds for infants, distraction sounds and words for toddlers, and encouragements for youngsters. Try, when age appropriate, to engage them in what is happening. Give them a sense of control by giving them small choices on what they want to do.

Image Gently: Technologist Check-off list for fluoro examinations (Pause & Pulse)

- Control voluntary and involuntary movement under the fluoro screen by using appropriate immobilization. Protect your patient by wrapping arms and legs in a small blanket or sheets.
- Comfort your patient with musical toys, favorite things from home, pacifiers, or when appropriate, positioning of a parent at the head of the table.
- Prioritize patient safety. Keep a constant eye on your pediatric patient. Focus on their response to the introduction of contrast, changes in their behavior, and maintain their position under the fluoro screen.
- Use tight collimation and child-size technique for overhead films required to complete the fluoro study.
- Record accurate fluoro times in the radiology patient documentation.

Section 3

Radiation Biology and Health Effects

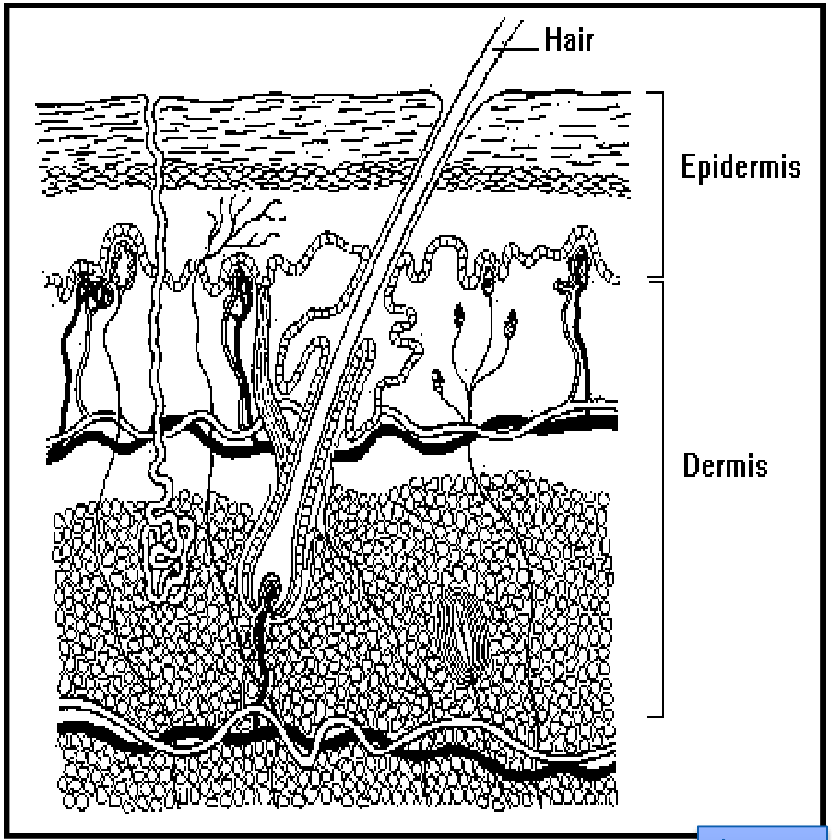
Why all the Concern About Lowering Dose?

Skin is radiosensitive (especially the basal cell layer)

Reports of serious **SKIN** injuries have been ever increasing

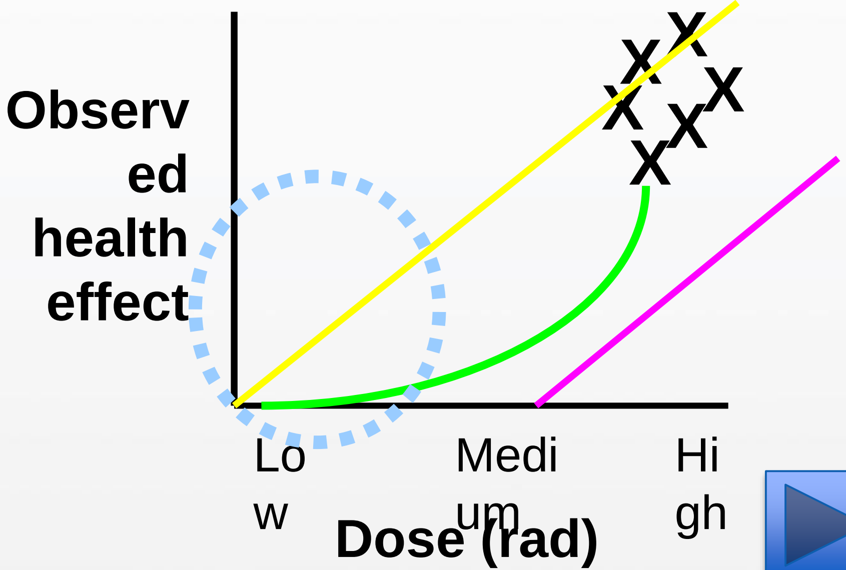
The threshold dose for a mild skin erythema is **2000 mGy (200 rad)**

When operating at 10 R/min, it only takes 20 min (10 min if in boost mode) to reach the threshold. This is for when the unit is operating at maximum output as with a very large patient



Skin Injury

- Skin injury is a **deterministic effect** which means a dose threshold exists, below which, the effects do not occur (shown as the purple line)
- The severity of the effect increases with dose above the threshold
- Only occurs with high acute doses, not chronic low dose
- The latent period (time of manifestation) shortens as the dose increases



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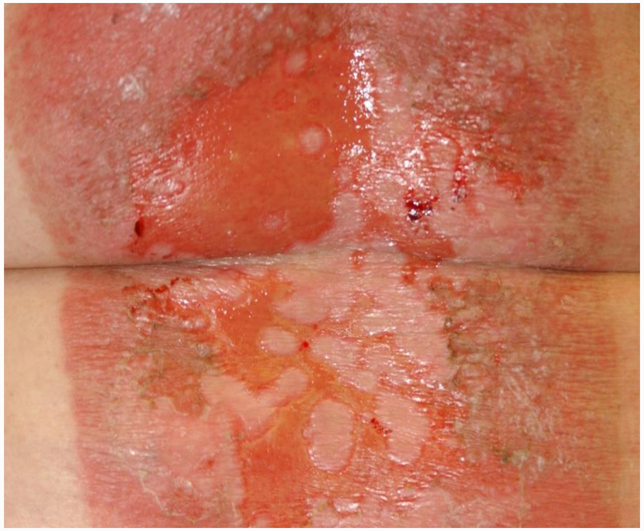
The table shows the expected skin injury symptoms at various dose ranges and the time of onset following fluoroscopy exposure

Single-site Skin Dose Range (Gy)	Prompt < 14 days	Early 14 – 40 days	Mid term 40 – 400 days	Long term > 400 days
0-2	No observable effects expected			
2-5	Transient erythema	Transient hair thinning	Hair recovery	None expected
5-10	Transient erythema	Erythema, epilation	Recovery from previous effects; at higher doses, possible prolonged erythema. Permanent partial epilation	Recovery, with possible permanent skin changes at higher doses in this range.
10-15	Transient erythema	Epilation, erythema. Possible moist desquamation at higher doses, with subsequent healing	Permanent total epilation. Prolonged erythema	Telangiectasia, induration. Skin likely to be weak and more susceptible to secondary injury.
> 15 *	Transient erythema and possibly pain. Edema and acute ulceration after very high doses (> 80 Gy)	Epilation, erythema, moist desquamation. Possible healing of acute ulceration.	Dermal atrophy. Secondary ulceration in areas of prolonged moist desquamation after higher doses. Dermal necrosis. Surgical intervention likely required; should be delayed until viable tissues are defined.	Telangiectasia, dermal atrophy/induration. Depending on dose and patient characteristics, any persistent wound might progress into a deeper lesion. Healing in absence of surgical correction likely to result in some or all of the following: scarred tissues, weak skin susceptible to injury, skin breakdown reoccurring at later dates.

WARNING

Images of skin injuries follow in the next two slides. Skip ahead two slides if you do not wish to view these



- The injury shown manifested 2 days after a “Renal Angiography” exam in a vascular surgery suite with a Philips Flat Panel C-Arm. The procedure used 103 min of fluoro time with 799 images acquired. The calculated dose was 13 Gy.
- Note the rectangular margins representing exactly the shape of the flat panel detector and x-ray beam size.
- Many RED FLAGS in this study including clinical obesity, dense anatomy, MAG mode used throughout, wide open collimation, no gantry rotation

- The injury shown manifested on both buttocks 3 days after a “Pelvic Arteriogram with Bilateral Uterine Fibroid Embolization” in an IR suite.
- The procedure used 30 min of fluoro time with 732 images acquired. The calculated dose was 12 Gy to right buttock & 8 Gy to left buttock.
- Many RED FLAGS in this study including clinical obesity, dense anatomy, boost mode used throughout, open collimation. The injury would have been much worst had the operator not alternated the gantry angle.

Radiation-Induced Cataracts

- Radiation exposure to the eye is a concern for workers due to the high radiosensitivity of the lens
- Unlike age-related cataract, when induced by radiation, manifestation is at the posterior pole
- May be caused by acute high doses or chronic lower doses with a wide variance in latent period
- The use of **lead eyeglasses** is recommended for high risk fluoroscopy operators (those who are generally at bedside while utilizing extensive fluoroscopy)
    - In **Massachusetts**, lead eyeglasses are *required* for those at bedside during **interventional fluoroscopic procedures**

Section 4

Radiation Protection Techniques

General Protection Techniques

Minimize **Time** in the vicinity of radiation sources:

- The relationship is directly proportional (doubling the time doubles the dose)

Stay as far away from radiation sources as possible:

- **Distance** follows inverse square law. Doubling your distance away drops dose by a factor of 4

Use **Shielding** between you & the radiation source:

- The use of lead to attenuate radiation follows an exponential relationship and is very effective

TIME, DISTANCE, SHIELDING!

How to Minimize Total "Beam-On" Time

Use short taps of the foot pedal and only when an interpreting physician is viewing the monitor

Use **last image hold** instead of continuing to fluoro just to view an image

Use pulsed modes

Be mindful of the 5 minute timer alarm

Be mindful of the use of boost and MAG modes

Boost Mode (High Level Control)

Use sparingly! May be for larger patients & to see fine detail

The boost mode pedal often has a (+) sign on the right

An audible signal sounds continuously to warn the operator that they are in boost mode

The radiation output may be legally up to 20 R/min!

Digital Acquire Mode

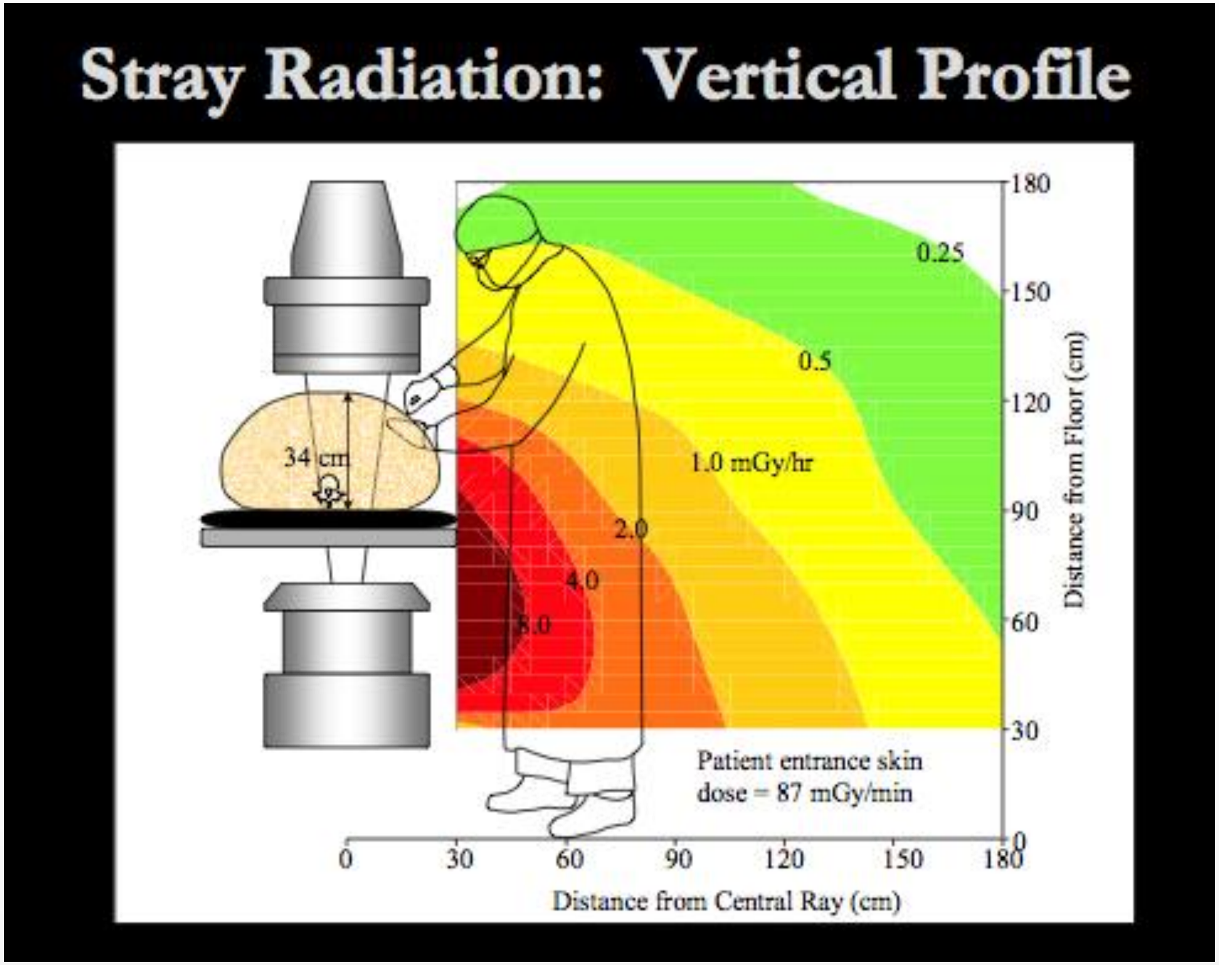
Digital acquire or “cine” mode captures high-resolution images with low noise.

The radiation dose per frame can be 15 times greater than for fluoroscopy.

Be mindful that image acquisition involves much higher doses

There are no limits of output (R/min) for acquisition

Distance



The dramatic reduction in dose with distance is easily visualized here

Courtesy Beth Schueler, Mayo Clinic

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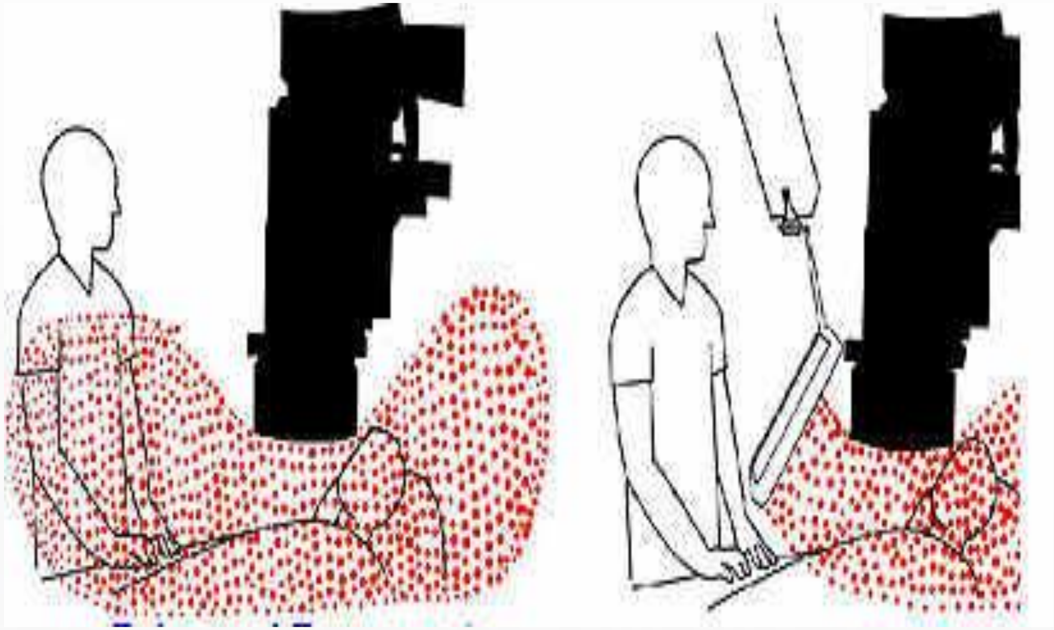
Shielding

Ceiling-mounted clear lead shields should always be used by fluoroscopy operators to protect from scatter if available



No shield in place – operator exposed to high scatter field

Shield in place – operator whole body is protected

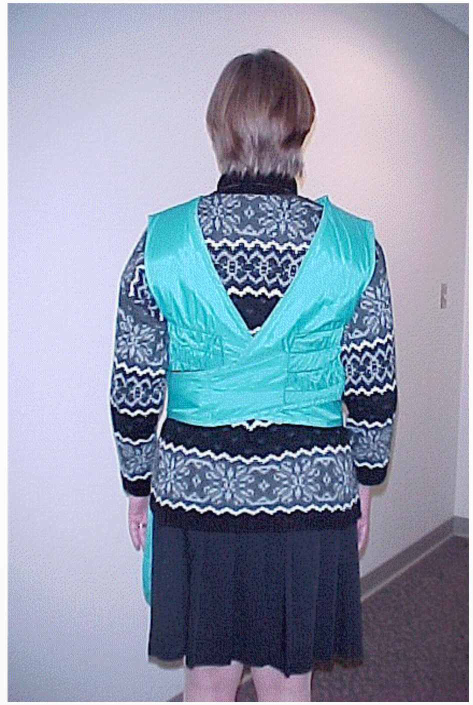
Some types have slatted lead for access

Shielding

Table-mounted lead shields can be clipped to either side of the table to protect the lower body and extremities

Table-mounted lead skirt shield

Personal Shielding



- Lead aprons are required for anyone within 6’ of an operating fluoro unit
- The minimum lead thickness equivalency is 0.25 mm
- The lead apron should fit properly front to back with no gaps. Note that frontal aprons have poor back side coverage.

Personal Shielding

- Lead eyeglasses should be worn by all fluoroscopy operators working at tableside in high risk rooms such as IR and Cath Lab
- These are generally owned by the employee for their own personal fit and prescription strength as needed.

- Thyroid shields should be worn by all fluoroscopy operators working at tableside in high risk rooms such as IR and Cath Lab

- Hang aprons on a rack designed for that purpose. NEVER pile up or fold aprons as the lead contents could shift.
- Before donning an apron, always check to ensure someone else's radiation badge isn't attached or in the pocket

Walk-Away Points

•Use Time – Distance – Shielding techniques to reduce dose

•Wear your radiation badge every day, over the lead apron, and return it on time each new month for analysis. Store badges in a designated radiation-free area when not in use.

•Fluoro operation is restricted to licensed practitioners, x-ray technologists, and residents within their scope of practice.

•Fluoro output (R/min) could be near the maximum allowed for patients who are clinically obese and/or when dense anatomy is being viewed.

•Patient dose is HIGHER with open collimation, MAG and boost modes, higher frame rates, large air gap, and long fluoro times.

Walk-Away Points

•Alternate the gantry angle during lengthy procedures to avoid irradiating the same patch of skin.

•Be aware of the reference dose display (mGy) on the system monitor and compare to the 2000 mGy awareness level. Be mindful of fluoro times greater than 30 minutes.

•Wear a lead apron if you are within 6’ of an operating C-Arm, and also a thyroid collar & lead eyeglasses if routinely at tableside in high-risk interventional or cath lab areas.

•The operator is responsible to ensure everyone is protected before energizing the tube.

•Contact the Radiation Safety Officer (RSO) if you:

- Have any radiation safety concerns or questions
- Lose your radiation badge or become pregnant and wish to obtain a fetal monitoring badge

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You must complete the competency quiz for course credit