# Radiation Protection of Patients

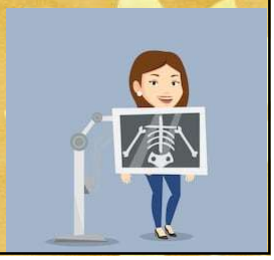
## Limiting Patient Exposures

Mrs. Heather Herb, B.S., R.T.(R)(M)
MI Program

1

# Always ask yourself..

## What is best for the patient?



2

# Holistic Patient Care

- Treat the patient as a whole rather than a body part
- Makes patient more respected, comfortable and more willing to cooperate
- Example: your patient is Mr. Smith, not the ankle x-ray

3

# Effective Communication Verbally & Body Language


- Introduce yourself
- Address the patient properly
- Ease the patient's stress and anxiety
- Show understanding and dignity
- Provide clear and concise instructions
- Increase their cooperation
- Give the patient time to ask questions
- Gain their trust
  - Tell them if there is discomfort or pain involved
  - Strange sensations
- Be professional, be present, watch body language
- Help to make the procedure successful
  - Reduces repeat exposures

4

# Patient Motion

- Involuntary
- Voluntary

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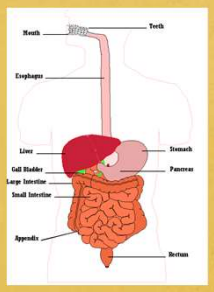
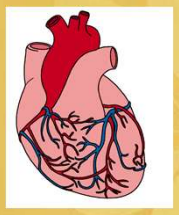
# Involuntary Motion

- Caused by muscles, not controllable
  - Heart
  - Digestive
  - Chills
  - Tremors
  - Spasms
  - Pain




- Corrected by reducing exposure time and increasing screen speed



6

# Voluntary Motion

- Controlled motion
- Sometimes there can be lack of that controlled motion due to:
  - Patient's age
  - Breathing patterns
  - Anxiety
  - Physical or mental discomfort
  - Fear
  - Mental instability

* Corrected by gaining patient cooperation and use of proper immobilization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# Immobilization

- Piggostat
- Papoose/Octostop
- Sponges and Sandbags
- Mummy wrap
- Tape
- Velcro straps
- Radiolucent plexiglass
- Having a non-radiology employee helping to hold

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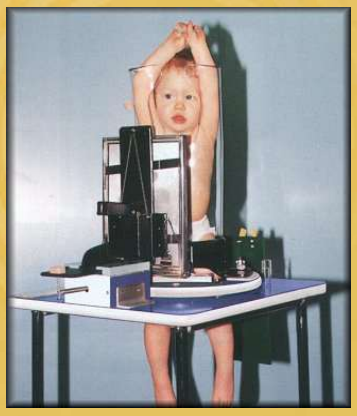
# Piggostat



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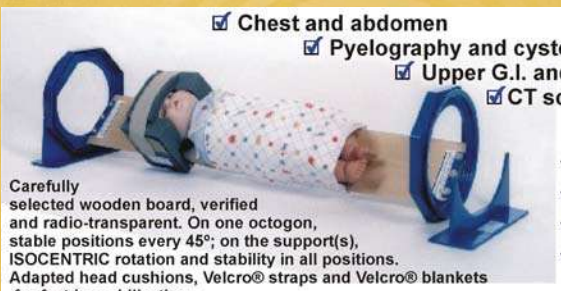
# Octostop

☑ Chest and abdomen
☑ Pyelography and cystography
☑ Upper G.I. and barium enema
☑ CT scan and MR



Carefully
selected wooden board, verified
and radio-transparent. On one octogon,
stable positions every 45°; on the support(s),
ISOCENTRIC rotation and stability in all positions.
Adapted head cushions, Velcro® straps and Velcro® blankets
for fast immobilization.

☆ *SIMPLE*
☆ *EFFICIENT*
☆ *INGENIOUS*
☆ *MODULAR*

☑ Skull and sinuses

Functions as a craniograph

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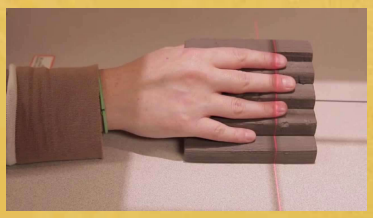
# Sponges (radiolucent) & Sandbags (radiopaque)

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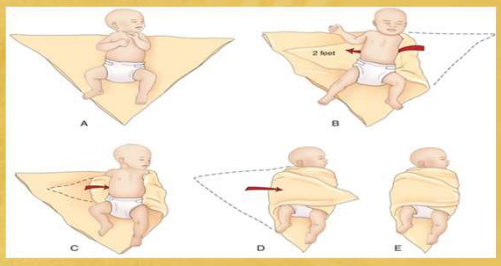
# Mummy Wrap

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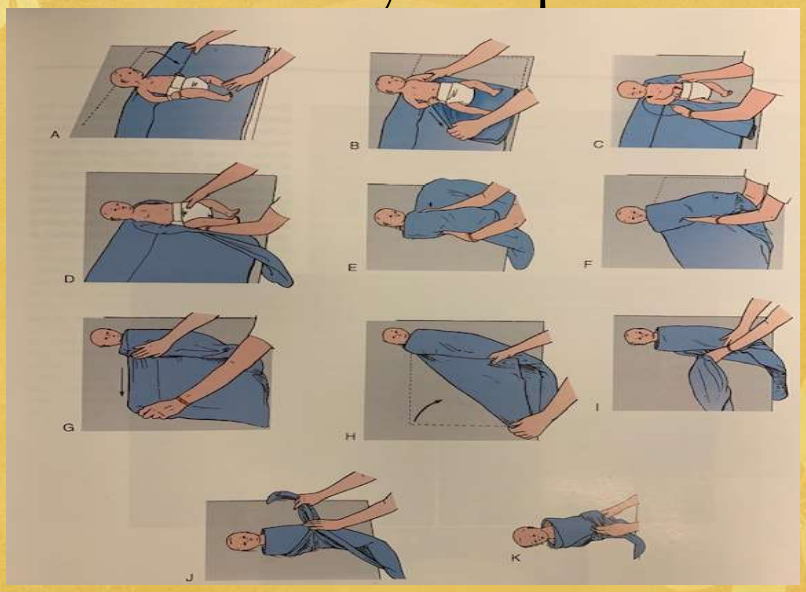
# Bunny Wrap

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# Beam Limiting Devices

- Limits the primary beam to a smaller area
- Decreases exposure by reducing the amount of tissue that is exposed (irradiated)
- Reduces scatter

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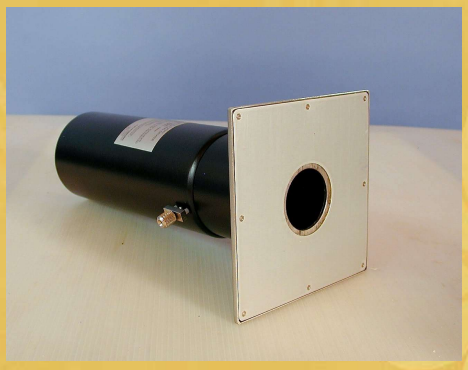
# Types of Beam Limiting Devices

- Aperture diaphragm
- Cones
- Collimators



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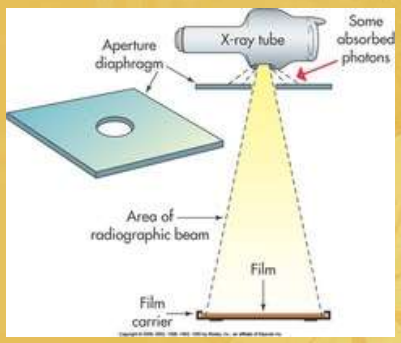
# Aperture Diaphragm

- Flat lead with a shape and size cut into it placed below the window
  - Rectangular
    - *most common
  - Square
  - Round
- Reduces scatter

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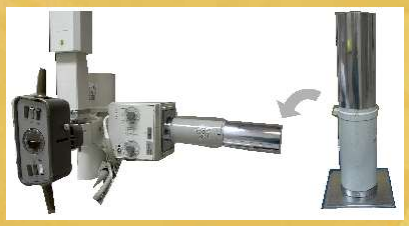
# Cones

- Circular metal cylinders connected to the tube housing that limits the size of beam
- Can be flared or straight
- Can be telescoped (10-12 inches) for smaller exposure area
  - called extensive cylinders
- Have mostly been replaced by collimators
- Mostly used in dental radiography but can be used for the heel, skull and spine imaging



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# Collimators

- Light-localizing variable aperture rectangular collimator
- Most versatile beam restriction
  - Can change size
- Should not be opened larger than the size of the image receptor or body part imaging
  - Post shuttering- part of ASRT Practice Standards
  - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3781259/
  - Can reduce exposure by 20-30%
- Careful not to over collimate which causes repeat images

**Beware of the Mask**

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# Collimators

- 2 sets of shutters 90 degrees from one another
  - **Near (upper)-**
    - Located close to the window
    - reduces exposure from off focus radiation
  - **Far (lower)-**
    - Located closer to the light source
    - confines the beam to the area of interest

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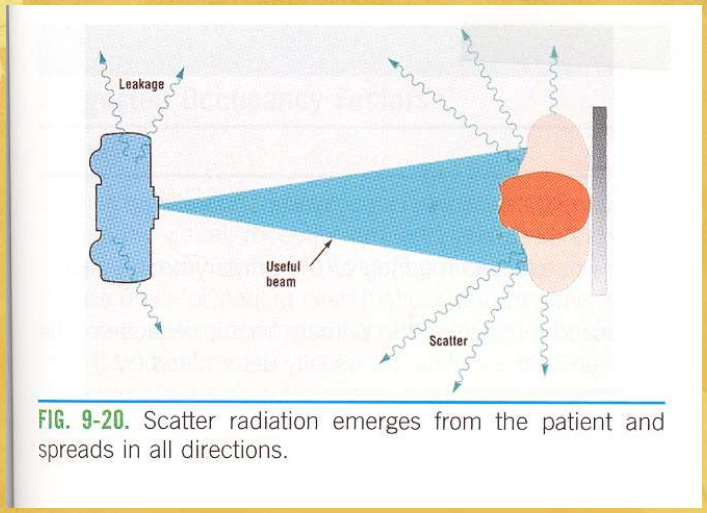


FIG. 9-20. Scatter radiation emerges from the patient and spreads in all directions.

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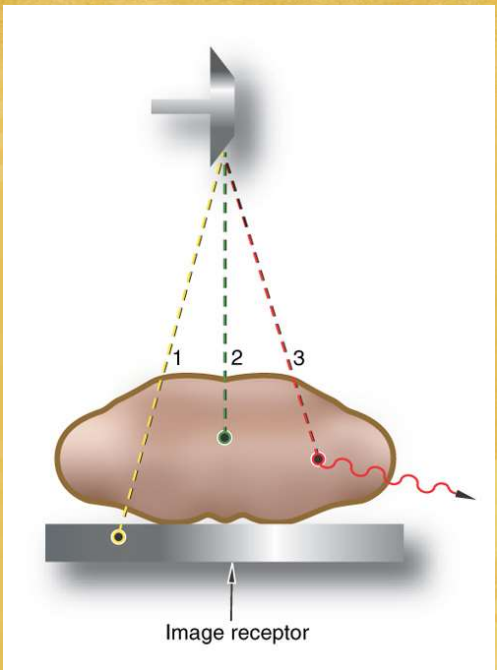
**Penetrated**

**Absorbed**

**Scatter**

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# Collimators

- Skin sparing
  - Minimizes skin exposure by requiring a 15 cm distance from the skin to the collimator
  - Can be achieved with spacer bars mounted on the tube

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# Collimators

- **PBL**
  - Positive Beam Limitation
  - Electronic sensors in the bucky that senses the image receptor size that you are using and opens the light field to that size
    - Can be slits or pegs
  - Reduces user errors by matching the light field to the image receptor size
  - Also known as ***automatic collimation***
  - Regulatory guidelines require this to be within 2% accuracy

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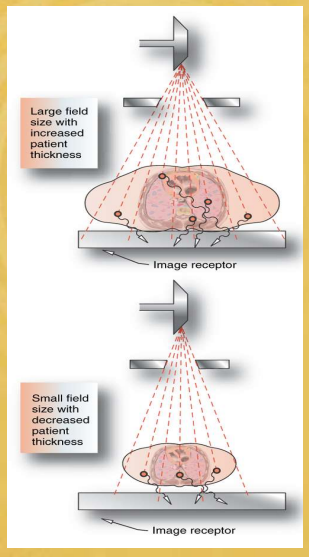
# Collimation Effects on Scatter

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# Filtration

- Hardens the beam by cleaning up the low energy (long wavelength) x-rays
- Reduces the skin and superficial exposure to the patient
- Decreases patient's absorbed dose because the remaining photons are higher energy (short wavelength)
- Lower energy photons (which were removed) would be more likely to be totally absorbed and provide no detail to the image
- Total filtration built in to the housing is **2.5mm Al** equivalent for units operating above 70kVp

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# Filtration

- 2 types
  - Inherent- **0.5mm Al equivalent**
    - Glass envelope, insulating oil, and glass window
  - Added- **2.0mm Al equivalent**
    - Sheets of Al added outside the glass window above the collimator shutters
    - Accessible to service person
    - Can be changed as the tube ages

*Mobile and Fluoroscopy units also require 2.5mm

*NCRP #102- list minimum required filtration for x-ray equipment

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# Filtration

- Radiation Control for Health and Safety Act of 1981 states that a diagnostic x-ray beam must always have adequate filtration
  - To verify that a machine has adequate filtration, the HVL (half value layer) must be measured (Carroll, p.675)
    - Measures beam quality or effective energy of the beam
    - Measured at least once a year by a physicist or if the tube is replaced or repairs are made

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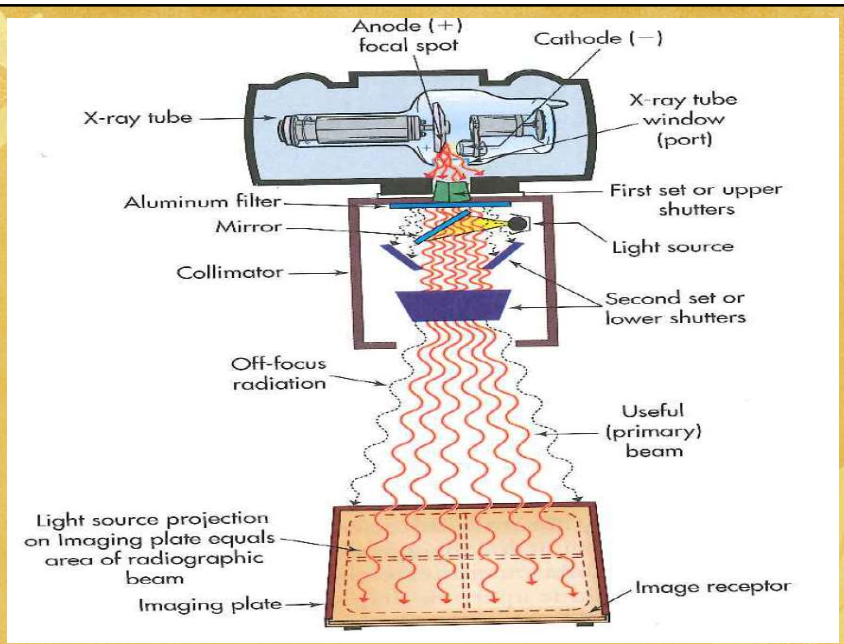


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# Shielding

- Needed to reduce exposures to radiosensitive organs to prevent biologic damage
  - Lens of eye
  - Breasts
  - Reproductive organs
- 2 types
  - Gonadal
  - Specific area

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# Gonadal shielding

- Should be used if the gonads are in or within 5 cm of the collimation
- Used unless covering the area of interest
- First step to gonadal protection is proper collimation

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# Use of Gonadal Shields

- Due to the anatomical location, females receive 3X more exposure than males
- Appropriate shield placement can reduce the exposure to
  - *females by 50%*
  - *males by 90-95%*

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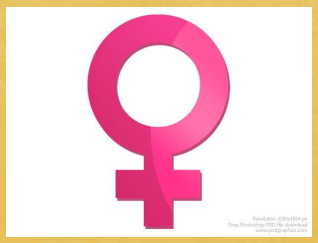
# Shield Placement for Females

- Contact or Shadow
- Place shield at the level of ASIS and centered to the body
  - The ovaries are 1 inch medially to the ASIS (anterior superior iliac spine) and the shield should extend to ½ inch above the superior rim of the symphysis pubic



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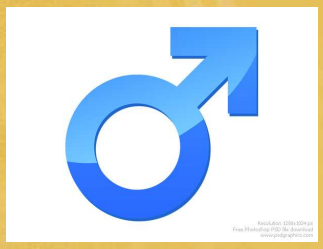
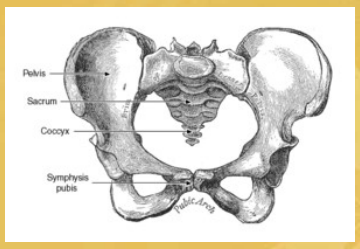
# Shield Placement for Males

- Contact or Shadow
- Place shield directly below symphysis pubis and centered to the body



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# Types of Shields

- Types
  - Flat contact
    - Fig Leaf
  - Shadow
  - Shaped contact
  - Clear lead
  - Half shield

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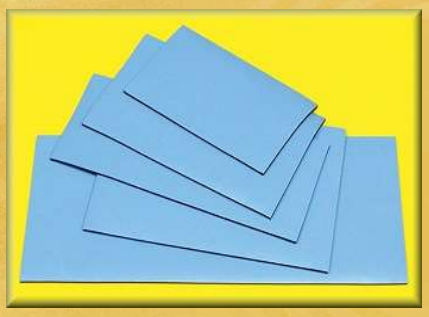
# Flat Shields



- Most effective in the AP or PA recumbent positions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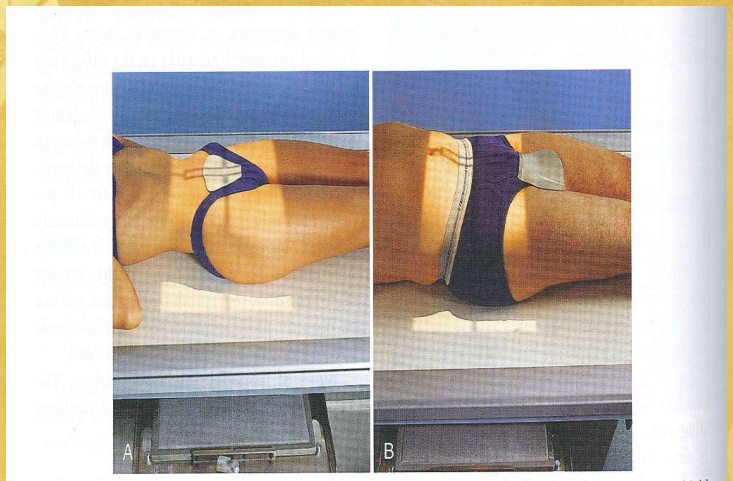


FIGURE 12-5 A, Contact shield correctly placed over the reproductive organs of a female patient. B, Contact shield correctly placed over the reproductive organs of a male patient.

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# Shadow Shields

- Careful to place properly or a repeat image could be caused
- Not suitable during fluoro

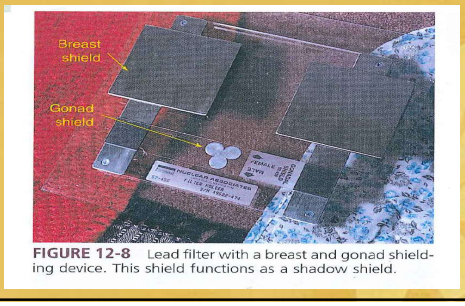


FIGURE 12-8 Lead filter with a breast and gonad shielding device. This shield functions as a shadow shield.

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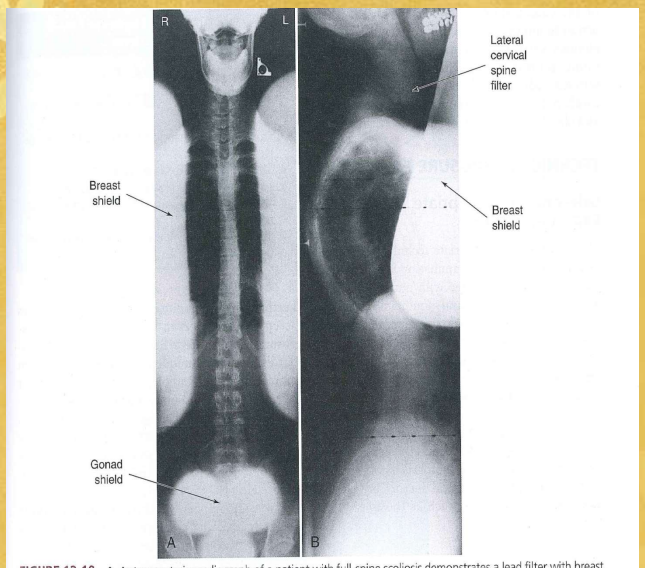


FIGURE 12-10 A, Anteroposterior radiograph of a patient with full-spine scoliosis demonstrates a lead filter with breast and gonad shields. B, Lateral radiograph of patient with full-spine scoliosis, with a lateral cervical filter and breast shield.

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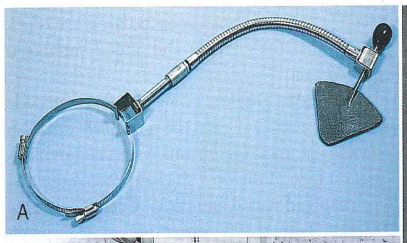


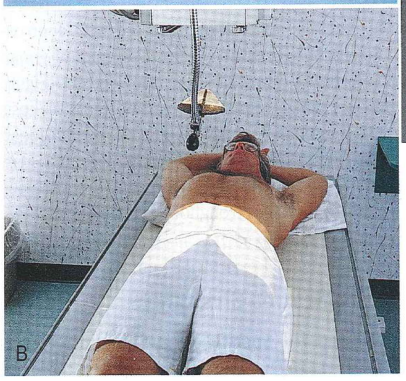


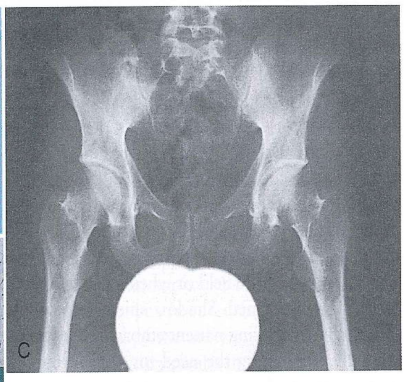


**FIGURE 12-7** A, Shadow shield components. B, A shadow shield suspended above the radiographic beam-defining system casts a shadow over the protected body area, the gonads. C, The radiographic image demonstrates effective gonadal shielding resulting from the use of a shadow shield.

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# Shaped Shields

**FIGURE 12-9** Shaped contact shields (cuplike in shape) may be held in place with a suitable carrier.

- Contoured to enclose the male reproductive organs
- Can be placed by the patient
- Can not be used during PA projections

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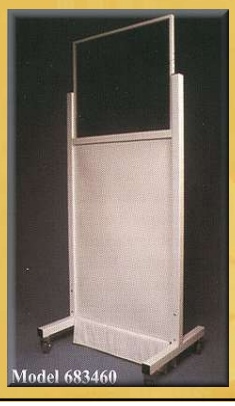
# Clear Shields

- Transparent lead-plastic material

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# Lap Shields (Half)

- Used in the department
- Covers only the front or back half of the patient
- Attached with a velcro strap or on wheels

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## Guidelines for Shielding According to the Center for Devices of Radiological Health

- If the gonads lie within or close to (about 5 cm from) the primary x-ray field despite proper beam limitation
- If the clinical objective of the examination is not compromised
- If the patient has a reasonable reproductive potential

*Merrills, Ed. 12 Volume 1 pg. 33*

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## Specific Area Shields

- Eyes
- Breast
- Thyroid
- Gloves


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# Compensating Filters

- Used when x-raying a part that has varying thickness to reduce dose and provide a uniform density across the image
- Decreases the entrance skin exposure (ESE)
- Constructed of aluminum or lead-acrylic that is attached to the bottom of the collimator
- Types
  - Wedge filter
    - Used for a foot and spines
  - Trough filter or bilateral wedge
    - Used on chest x-rays
    - Thicker on both sides and thin in the middle
  - Ferlic
    - Hips
  - Boomerang
    - Shoulders

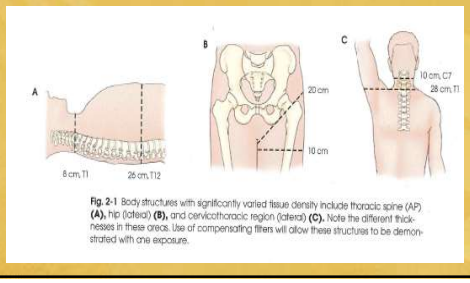


Fig. 2-1 Body structures with significantly varied tissue density include thoracic spine (AP) **(A),** hip (lateral) **(B),** and cervicothoracic region (lateral) **(C).** Note the different thicknesses in these areas. Use of compensating filters will allow these structures to be demonstrated with one exposure.

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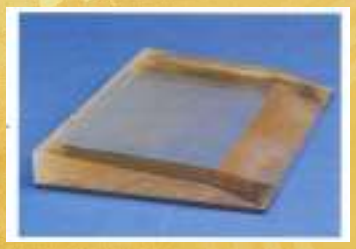
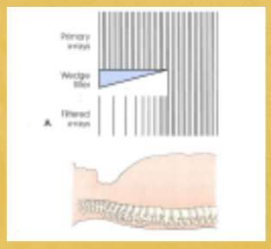
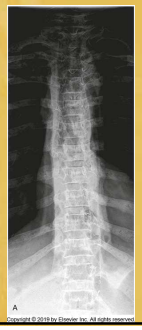
# Wedge Filter







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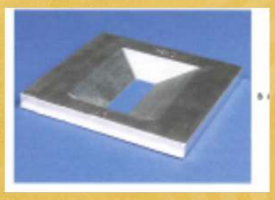
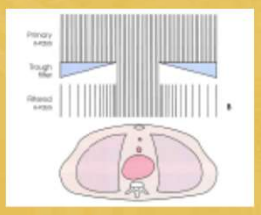
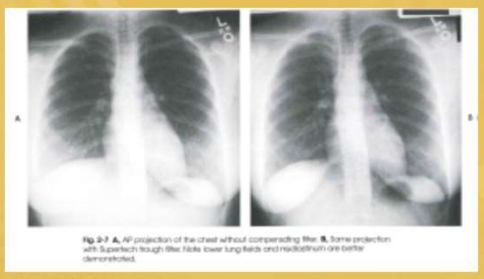
# Trough Filter







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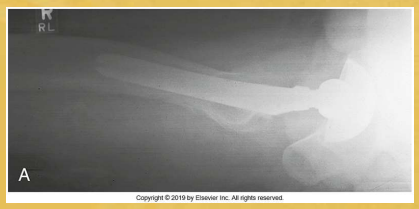
# Ferlic Filter







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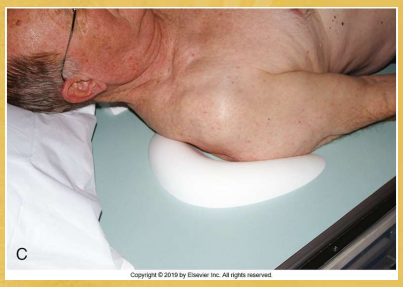
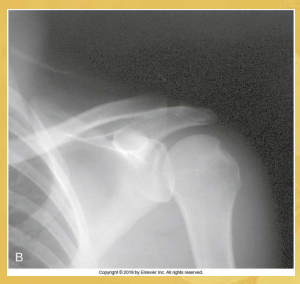
# Boomerang Filter





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# Basic X-ray Terminology

- kVp
  - kilovoltage peak
    - Maximum possible energy of a photon that exits the x-ray tube, this is a unit selected on the operating console
    - Indirectly proportional to patient exposure
- mA
  - milliamperage
    - Measurement of x-ray tube current or the number of electrons crossing the tube from cathode, this is a unit selected on the operating console
    - Directly proportional to patient exposure
- mAs
  - milliampere seconds
    - Controls the amount of radiation produced by the x-ray tube
    - mA X seconds= mAs
    - Directly proportional to patient exposure
- AEC
  - Automatic exposure control
    - the cells that are selected on the operating console that will automatically select the mA according to cell selection and body part

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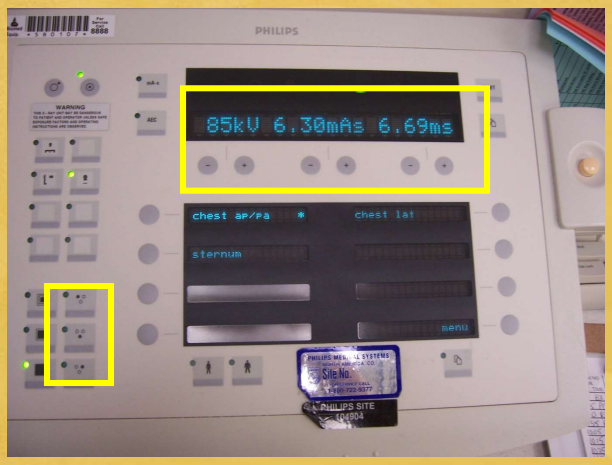


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# Exposure Index (EI)

- The number that is found on the image after processing to identify if the image was adequately exposed
- Examples in our department:
  - CR 1600-2100 (Kodak) - DIRECT
    - Below 1600 = Underexposed, increase technique
    - Above 2100 = Overexposed, decrease technique
  - DR 200-800 (Philips)- INDIRECT
    - Below 200 = Overexposed, decrease technique
    - Above 800 = Underexposed, increase technique
  - RM 7 & DR Digital Portable (Shimadzu) - DIRECT
    - 300-600 REX for chest x-rays
    - 200-400 REX for others

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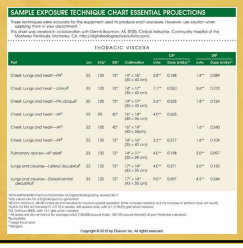
# Use Proper Exposure Factors

- Makes an optimal image with minimal dose possible
- Sufficient penetration
- Increase kVp , decrease mAs
- When setting manual technique, measure the patient for accuracy
- Reliable technique charts
- AEC
  - Automatic Exposure Control
  - Sets the appropriate mA for the body part being x-rayed by selecting cells


SAMPLE EXPOSURE TECHNIQUE CHART ESSENTIAL PROJECTIONS

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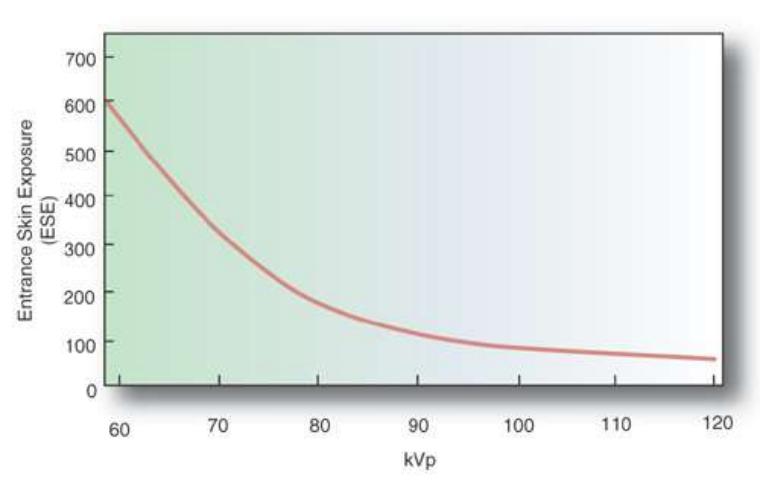
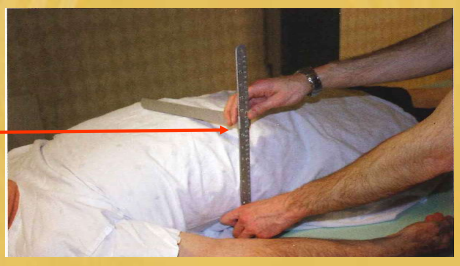
# kVp Effects on Entrance Skin Dose




55

# What We Use to Measure the Patient

Read from the bottom



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# Proper Film Screen Combos

- Increase in film screen speed decreases patient exposure but decreases sharpness
- Computed Radiography acts as a 200 speed image receptor
- Digital Radiography acts as a 200 or 400 speed image receptor

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# Correct Processing

- Inadequate processing results in repeats
- Careful loading and unloading of film is important
- Strict quality control standards need to be maintained

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# Radiographic Grids

- Rule of thumb is to use a grid when part thickness is over 10cm
- Removes scatter photons that come from the patient before they reach the image receptor
- Improves the contrast and detail of the image
- Grids increase patient dose but improves the quality of the image which provides a better diagnosis
  - Use the lowest grid ratio sufficient for the body part

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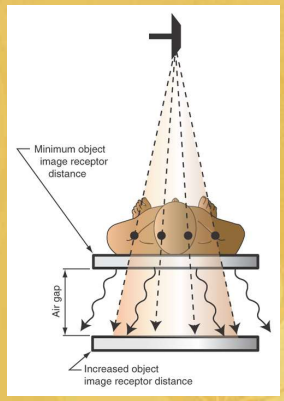
# Air Gap Technique

- Alternative to using a grid to clean up scatter
- Patient is placed 6-10 inches (10-15 cm) away from the image receptor with a 10-12 feet SID
- Negative side is the increase in magnification and not useful in kVp higher than 90

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# Eliminating Repeats will Decrease Patient Exposure

- Repeat image- is any image that must be done more than once due to human or mechanical errors
- Patient receives a "double dose"
- Repeats are unacceptable if done due to carelessness or poor judgment
  - Positioning
  - Technique


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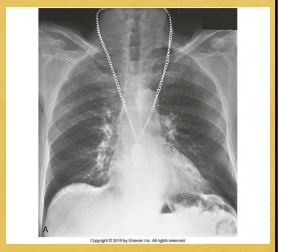
# Repeat Analysis

- Problems with positioning
- Incorrect centering
- Inappropriate technical factors
- Improper collimation
- Foreign bodies
- Processing artifacts
- Patient motion



| DATE | DIAGNOSTIC LOCATION | TOTAL IMAGES CONFIRMED | TOTAL REJECTS | REPEAT RATE |
|---|---|---|---|---|
| May-16 | total equipment | 26511 | 1576 | 5.9% |
| | | | | |
| | | | | |
| | total cr readers | 2472 | 114 | 4.6% |
| | TOTAL OVERALL | 28983 | 1690 | 5.8% |

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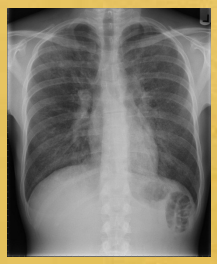
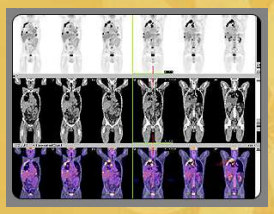
# Avoiding Unnecessary Procedure to Reduce Patient Exposure

- Chest x-rays
  - Pre admission
  - Pre employment
  - Routine health check ups
  - Screening for TB
- Lumbar x-rays
  - Pre employment
- CT whole body scans
  - Check for disease





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# Mobile Radiography

- Minimal source to skin distance on a mobile fluoroscopy unit is ***12 inches (30 cm)***
- The smaller the source to skin distance the larger the entrance exposure
- Only perform portable x-ray on patients that cannot be transported to the department

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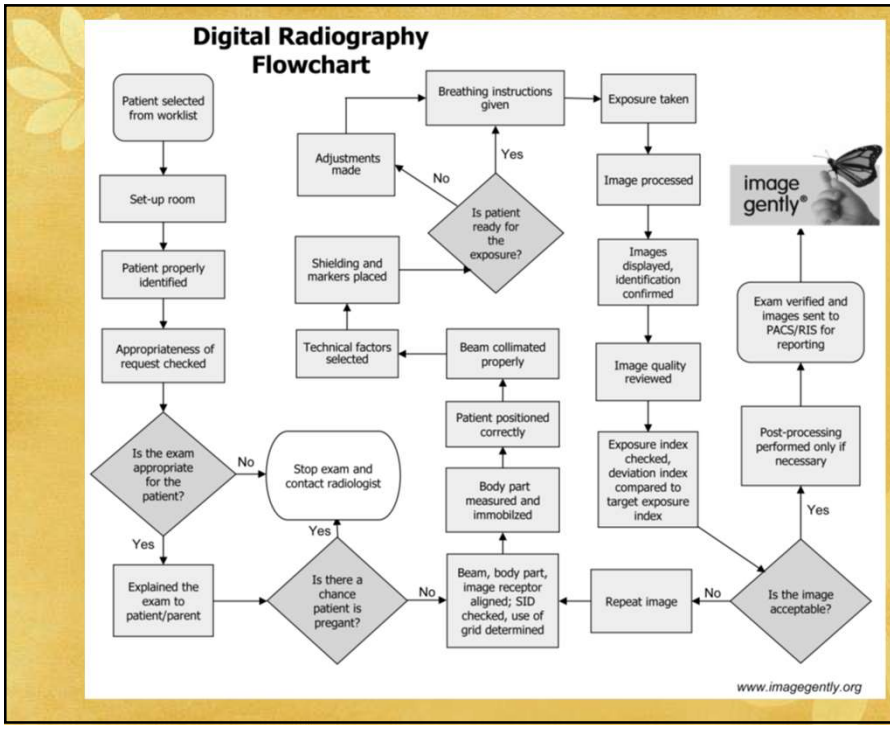
# Digital Imaging & Computed Radiography

- Just because the image is able to be manipulated, does not excuse over exposing the patient
- Utilization of technique charts
- Grids

65

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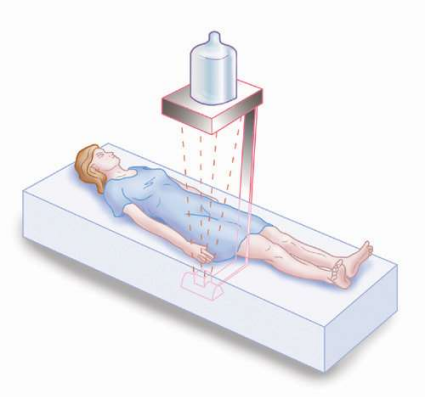
# Fluoroscopy

- Largest exposure to patients in radiology



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# Limiting Exposures in Fluoroscopy

- Image Intensification
  - Increases brightness on screen
- Intermittent or pulse fluoro
- Limit magnification mode
- Limiting field size
- Techniques
- Filtration
  - Reduces skin dose
- Shielding
  - Underneath the patient if the tube is under the table
- Source to skin distance
  - NCRP states ***15 inches (38 cm) for fixed units and 12 inches (30 cm) for mobile***

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# Limiting Exposures in Fluoroscopy

- Cumulative timing device
  - Audible alarm or interrupt of fluoro at 5 minutes on time
  - The technologist is responsible to record the fluoro time in the electronic medical record
- Federal regulations for table top exposure rates are 88 mGy per minute
- Primary protective barrier
  - 2 mm lead equivalent for II built in the equipment
- Automatic Brightness Control/ Stabilization (ABC/ ABS)
  - No matter the kVp or mA varying, the brightness of the image remains the same
- Automatic Exposure Rate Control (AERC)
  - Adjusts exposure factors automatically as the beam moves over varying thicknesses
- Fluoro exposure switch

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# Dead Man Switch

- Foot pedal requires direct pressure to continue fluoro
- So if the user would "fall over dead" the exposure would stop


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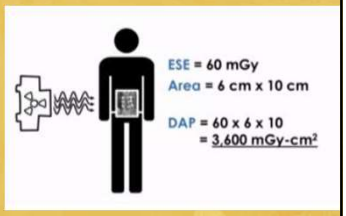
# Digital Fluoroscopy

- Beam turns off while image is scanned and then turns back on
  - Pulsed
- Dose Area Product (DAP)
  - Newer fluoro systems provide the sum of the air kerma (energy) over the exposed area of he patient
- Last image hold
  - When the foot comes off the pedal, it holds the last image and displays it on the screen until the foot pedal is activated again

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# Fluoroscopically Guided Positioning

- FGP
- Using fluoroscopy to determine if you are positioned appropriately before taking an image
- ASRT stand is that this practice is unethical and should never be used

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# C-arm Fluoroscopy

- Used in the OR, Cardiac Cath, and IR
- Lengthy cases have the potential for high patient doses
- Properly trained personnel to work the equipment
- *12 inch (30 cm) minimal distance to the patient*
  - Spacers are usually placed to maintain a safe distance
- C-arm should be positioned with the II on the top
  - Reduces scatter and patient dose

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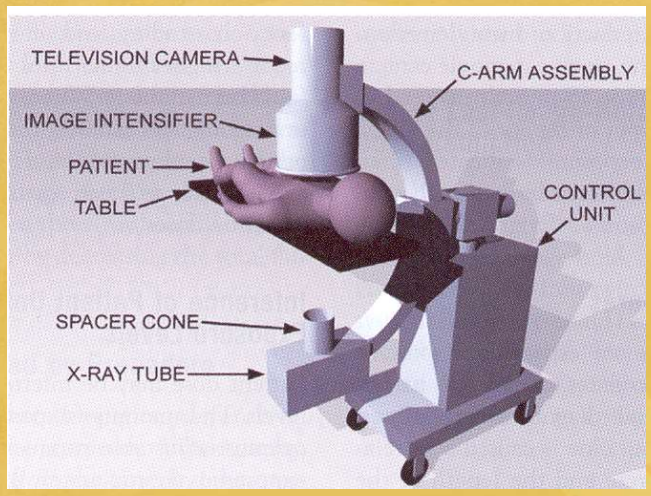


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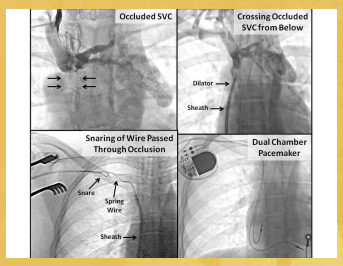
# Cinefluoroscopy

- Used in cardiology and neuro-radiography
- Works like a movie
- Reduce patient exposure
  - Limit time without losing information
  - Collimate
  - Last frame hold

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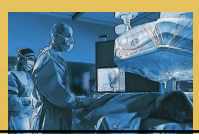
# Interventional Radiology

- Invasive sterile procedures performed by a physician under fluoro
- FDA requires documentation in the patient chart if skin dose is 1-2 Gy
- Federal regulations for table top exposure rates for procedures with high level control fluoro (HLCF) exposure limits are 176 mGy per minute
  - HLCF allows for visualization of smaller and lower contrast objects
- Should be performed by an educated and trained physician
  - Keeps patient doses and occupational doses down



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# Radiation Patient Dose Measurements

- Entrance Skin Exposure (ESE)
  - Includes skin and glandular
- Skin Dose
  - Absorbed dose to the most superficial layers
- Gonadal Dose
  - Genetically significant dose (GSD)- assess the effects of gonadal dose
    - Approximate dose in US is 0.2mSv
- Bone Marrow Dose
  - Dose to entire active bone marrow
  - Also known as the mean marrow dose

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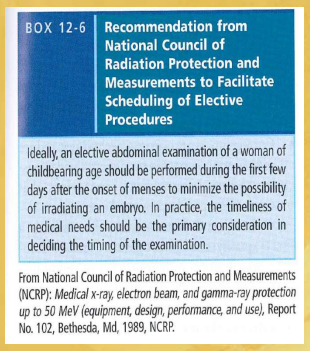
# Pregnant Patient

- Asking LMP (last menstrual period)
  - RH policy should be followed
- 10 day rule
  - ICRP recommendation from 1970
- ACR's position on pregnant patients
- Elective exams should be scheduled according to the 10 day rule
- 10-25 rad rule
  - <10- ok
  - 10-25- consider options
  - >25- not good
- Radiology departments are responsible to post pregnancy signs



BOX 12-6 **Recommendation from National Council of Radiation Protection and Measurements to Facilitate Scheduling of Elective Procedures**

Ideally, an elective abdominal examination of a woman of childbearing age should be performed during the first few days after the onset of menses to minimize the possibility of irradiating an embryo. In practice, the timeliness of medical needs should be the primary consideration in deciding the timing of the examination.

From National Council of Radiation Protection and Measurements (NCRP): *Medical x-ray, electron beam, and gamma-ray protection up to 50 MeV (equipment, design, performance, and use)*, Report No. 102, Bethesda, Md, 1989, NCRP.

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**BOX 12-7 Position of the National Council of Radiation Protection and Measurements Concerning Risk and Fetal Exposure with Regard to Termination of Pregnancy**

This risk is considered to be negligible at a fetal absorbed dose of 5 cGy or less when compared with other risks during pregnancy. The chance of malformations is significantly increased above control levels only at doses beyond 15 cGy. Therefore, the exposure of the fetus to radiation arising from diagnostic procedures would rarely be cause, by itself, for terminating a pregnancy. If there are reasons other than possible radiation effects to consider a therapeutic abortion, the attending physician should discuss those reasons with the patient so that it is clear that the radiation exposure is not being used as an excuse for terminating the pregnancy.

Adapted from National Council on Radiation Protection and Measurements (NCRP): *Radiation protection in pediatric radiology,* Report No. 68, Washington, DC, 1977, NCRP.

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# What if We Have to X-ray a Pregnant Patient?

- Minimize the dose
  - Smallest exposure that will produce optimal images
- Collimate
- Lead apron should be provided if not in area of interest
- RH patient must sign a consent form if the pelvic/ abdomen area is being x-rayed

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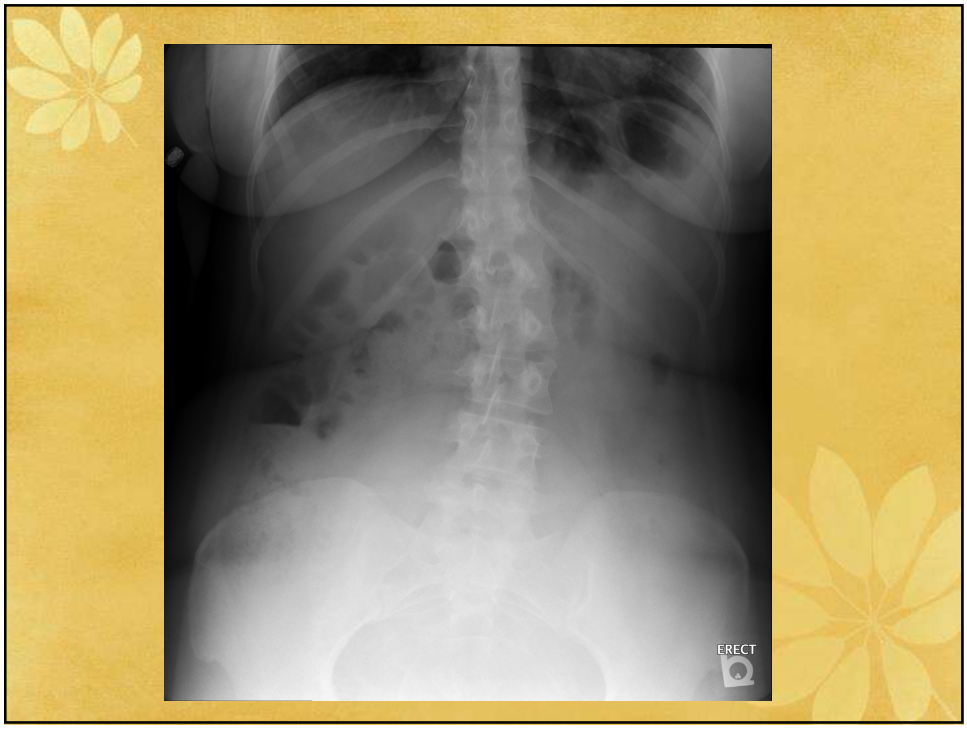


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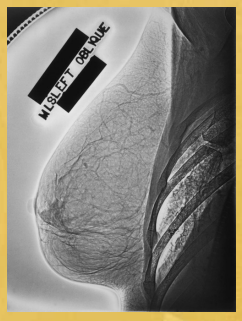
# Mammography

- Utilizes low kVp
- Limit number of projections
- Adequate compression
- Avoid axillary exposure unless ordered by radiologist

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# CT

- Doses are higher than diagnostic radiology
- Shielding is usually not utilized because of the nature of the exposure
- Collimators are very tight in CT, exposure is caused by internal scatter

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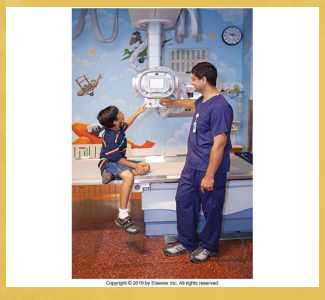
# Pediatric Patients

- More sensitive to exposure due to rapidly dividing cells
- Due to their longer life span it can increase chances of developing a radiation induced leukemia or a radiogenic malignancy such as *lung or thyroid*



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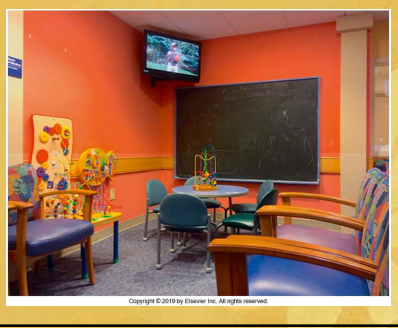
# Decreasing Exposure to Pediatric Patients

- Communicate at their level
- Minimize repeats
- Minimize number of images taken
- Use collimation
- Use short exposure times/ appropriate exposure factors
  - Less exposure is needed to obtain optimal images
- Shield
- Immobilization

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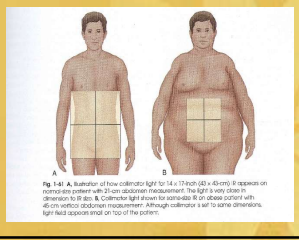
# Morbid Obesity

- Have patient centered to table because landmarks are hard to palpate
- Skeletal anatomy does not change in position and organs are not larger except:
  - Thoracic cage expanded 2″
  - Stomach may slightly be larger
  - Colon may spread out
- Increase kVp to increase penetration of the x-ray beam
- Use grids to clean up scatter
- In most cases it is not appropriate to increase the image receptor size
  - Smaller collimation decreases scatter



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# Image Gently Campaigns

- **CT**- One Size Does Not Fit All
- **Digital**- Back to Basics
- **NM**- Go With the Guidelines
- **Fluoro**- Pause and Pulse
- **AIR**- Step Lightly

Child focus: www.imagegently.org
Adult focus: www.imagewisely.org

*Resources for these campaigns are found of Edvance






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# Equipment Safety

- On and off switches
- Interlocks
  - Detents
  - Fluoro locks
- Visual/ audio monitors
  - Control panel
  - Laser light
  - Tape measures
- Emergency controls

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