Chapter 11

Radiobiology and Radiation Safety

Learning Objectives

- State the units used to measure radiation exposure, absorbed dose, and equivalent dose in both the conventional system and the Système International (SI)
- Discuss the potential effect of radiation injury to cells
- Define and compare radiation risks according to type: somatic vs. genetic, short term vs. long term
- Discuss the risks of exposure to low doses of ionizing radiation and compare these with other familiar health risks
- Explain the significance of the As Low As Reasonably Achievable (ALARA) principle

Learning Objectives (Cont'd)

- List and explain methods for minimizing patient dose during radiography
- Explain what is meant by low-dose techniques
- List and explain precautions for the safety of limited operators
- List potential risks of radiation exposure during pregnancy and explain ways to reduce these risks

Radiation Measurement

- Système International (SI) Units
  - Established in 1980 by the International Commission on Radiation Units
- Conventional and new SI Unit Equivalents

Conventional Units	SI Units
Roentgen	Air Kerma (Gy_a)
Rad	Gray (Gy_t)
Rem	Sievert (Sv)

Entrance Skin Exposure (ESE)

Patient dose in radiography is usually calculated according to the exposure level at the skin

Biologic Effects

- Cellular effects of radiation
  - Results include:
    - Cell death
    - Cell malfunction
    - Cell abnormalities

Biologic Effects (Cont'd)

- *Law of Bergonié and Tribondeau*
- Degree of sensitivity depends on:
  - Age of cell
  - Differentiation or complexity of cell
  - Metabolic rate or how much energy the cell uses
  - Mitotic rate or how quickly the cell reproduces

Biologic Effects (Cont'd)

- Cells and tissues with increased sensitivity include:
  - Blood cells
  - Skin
  - Mucous membranes of the mouth, nose, stomach, and bowel
  - Thyroid gland
  - Breast
  - Those of embryos, fetuses, infants, children, and adolescents

Classification of Radiation Effects

- Effects
  - Short term – occur within 3 months
  - Long term – occur within 5 to 30 years
  - Somatic – affect body and tissue of those irradiated
  - Genetic – are observed as defects in offspring of irradiated individual

Classification of Radiation Effects (Cont'd)

- Short-Term
  - Observed within 3 months of exposure
  - Associated with radiation doses >2,000 mSv
  - Effects are predictable
  - Severity of the effect is proportional to dose
  - Further categorized as:
    - Hematologic
    - Gastrointestinal
    - Central nervous system

Biologic Effect of Whole Body Dose

250 mSv = Blood changes

2,000 mSv = Erythema

6,000 mSv = Death

Classification of Radiation Effects

- Long-Term or Latent
  - May not be observed for as long as 30 years
  - Greatest percentage occurs between 10 and 15 years
  - Effects are unpredictable
  - Severity of effects are unrelated to dose
  - Further categorized as:
    - Somatic or occurring within the exposed individual
    - Genetic or occurring within the children or grandchildren of the exposed individual

Long Term Effects

- Cataracts
- Carcinogenesis
- Life-span shortening
- Leukemia

Comparative Risk

- Benefits from radiographic procedures outweigh the risks of radiation exposure
- On average, people receive an annual dose of 6.3 mSv from a variety of sources such as:
  - Radiation from space
  - Radon gas
  - Medical procedures (mainly CT scans)

Patient Radiation Safety

- Based on the principle that radiation dose is kept As Low As Reasonably Achievable (ALARA)
- Unnecessary patient dose from repeat radiographs can be reduced by:
  - Confirming patient identity and exam to be performed
  - Reducing the number of repeat x-rays
  - Using the smallest radiation field
  - Using the highest kVp for the body part
  - Using an SID minimum of 40 inches

Patient Radiation Safety (Cont'd)

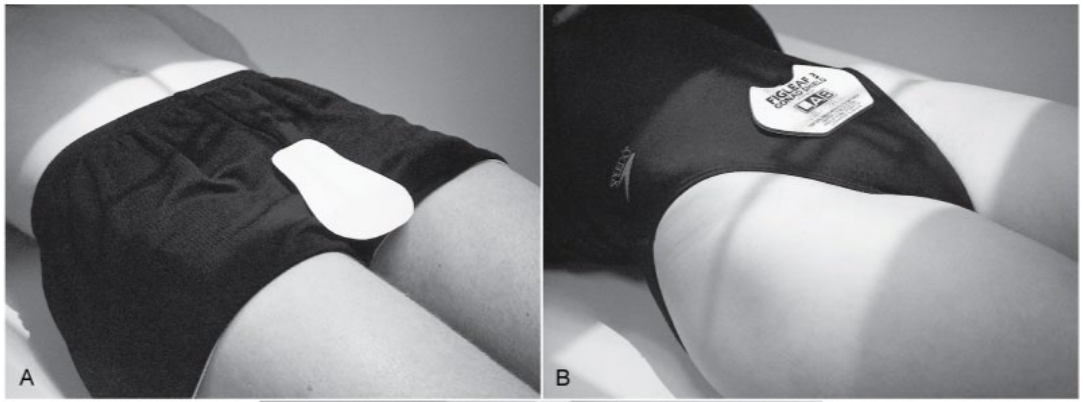
The greatest cause of unnecessary radiation to patients that can be controlled by limited operators is repeat exposures

Patient Radiation Safety (Cont'd)

- Gonad shielding:
  - Prevents genetic effects from radiation
  - Is used primarily with patients younger than age 55
  - Must be at least 0.5-mm lead equivalent
  - Is used when gonads are within 5 cm of the margin of the radiation field

Patient Shielding

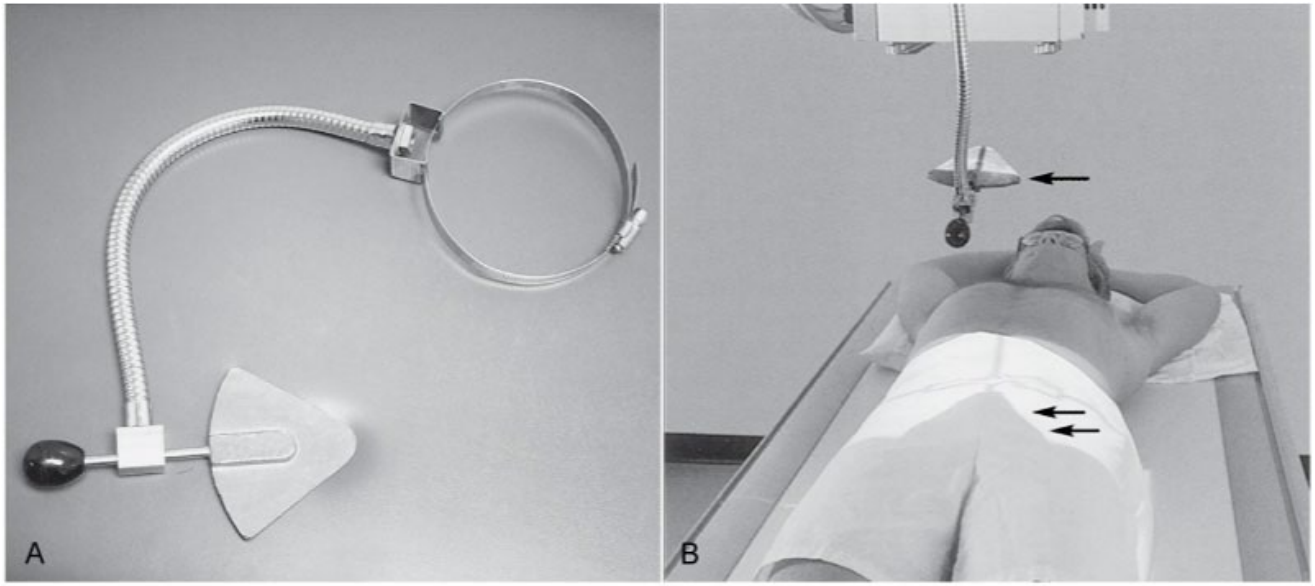
- Shielding guidelines
  - Use for patients of reproductive age and younger when gonads are within or near the primary x-ray beam
  - Shield should not obscure desired anatomy



Frank ED, Long BW, Smith BJ: *Merrill's atlas of radiographic positioning and procedures*, ed 12, St Louis, 2012, Mosby.

Patient Shielding (Cont'd)

- Shields
  - Consist of at least 0.5-mm lead equivalent
  - May be classified as contact (placed directly on patient) or shadow (attached to the collimator)



Ballinger PW, Frank ED: *Merrill's atlas of radiographic positions and radiologic procedures*, ed 10, St Louis, 2003, Mosby.

Personnel Radiation Safety

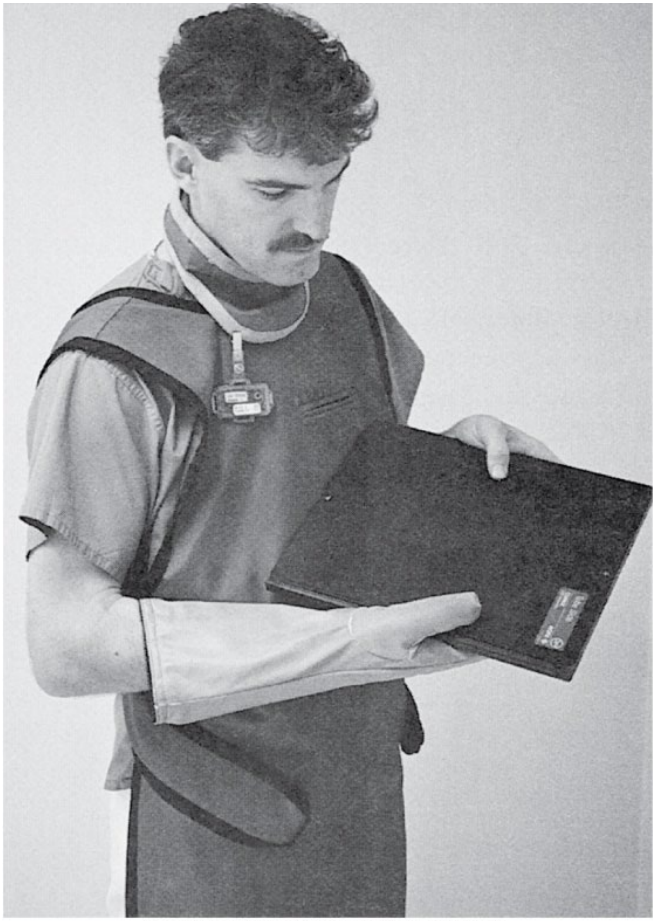
- Occupational workers such as limited operators should never hold or restrain a patient during an exposure
- Mobile and fluoroscopic procedures pose the greatest risk for radiation exposure of limited operators
- Methods for reducing amount of exposure include:
  - Time
  - Distance
  - Shielding

Personnel Radiation Safety (Cont'd)

- Time
  - Minimize amount of time spent in radiation field and x-ray room
- Distance
  - Maximize the distance from the radiation source
- Shielding
  - Remain behind the shielded control panel during routine exposures
  - Wear appropriate safety apparel during mobile and fluoroscopic procedures

Personnel Shielding

- Radiation safety apparel includes:
  - Gloves
    - 0.25 mm
  - Aprons
    - 0.5 mm
  - Thyroid shield
- Check twice a year



Ehrlich RA, Daly JA. *Patient care in radiography.* ed 7, St Louis, 2009, Mosby.

Monitoring Personnel Exposure

- Radiation dose measured with a dosimeter:
  - Required when the limited operator may receive 10% of annual exposure of 50 mSv
  - Attached to the collar region on the front of the body
  - Remains outside the lead apron
  - Personnel dosimeters are mostly:
    - Optically stimulated luminescence (OSL)
    - OSLs can measure small doses more precisely
    - OSLs are accurate over a wide dose range

Effective Dose Limits

- NCRP (National Council on Radiation Protection and Measurements) effective dose limits for x-ray operators:
  - Annual = 50 mSv (5 rem of the old system)
  - Cumulative = Age x 10 mSv (Age x 1 rem of the old system)

Radiation and Pregnancy

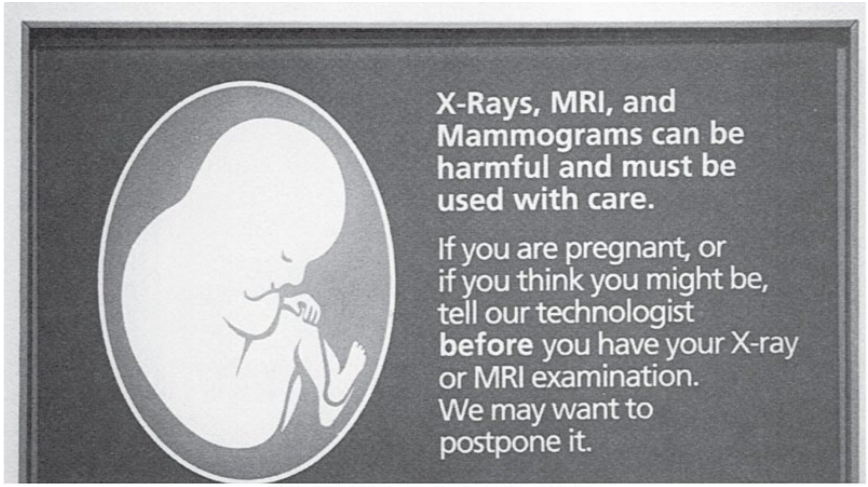
- Radiation risks are greatest during the first trimester and may include:
  - Abortion
  - Fetal death
  - Birth defects
- NCRP limit for a pregnant operator is:
  - *0.5 mSv* each month (or 0.05 rem old system)
  - *5.0 mSv* for entire pregnancy (or 0.5 rem old system)

Radiation and Pregnancy (Cont'd)

- The limited operator's declaration of pregnancy:
  - Is voluntary
  - Must be in writing
  - Gives the employer the responsibility of ensuring the fetal dose limits are not exceeded

Radiation and Pregnancy (Cont'd)

- For patients of reproductive age
  - Prior to the procedure, advise patients of potential risk of exposure during pregnancy
- If the patient is pregnant:
  - Physician determines whether to proceed



Ehrlich RA, Daly JA: *Patient care in radiography,* ed 7, St Louis, 2009, Mosby.

Summary

- Radiation units may be conventional or Système International (SI)
- In the United States, the SI units of exposure are the Air Kerma, Gray, and Sievert

Summary (Cont'd)

- Radiation sensitivity depends on cell age, differentiation, metabolism, and mitotic rate
- Cells and tissues with increased sensitivity include blood cells, skin, mucous membranes, thyroid, breast, and those in patients who are adolescents or younger

Summary (Cont'd)

- Classifications of radiation effects include short-term or non-stochastic, long-term or stochastic, genetic, and somatic
- Benefits of radiographic procedures outweigh the risks of radiation exposure
- Patient radiation protection follows the ALARA principle
- ALARA includes reducing the number of repeat radiographs, collimating, shielding, and applying low-dose techniques

Summary (Cont'd)

- Limited operators must never hold or restrain a patient during an exposure
- Radiation exposure to limited operators is reduced during mobile and fluoroscopic procedures by following time, distance, and shielding guidelines
- Dosimeters are worn in the collar area to monitor radiation dose received by limited operators

Summary (Cont'd)

- Radiation risks are greatest during first trimester of pregnancy
- The declaration of pregnancy for a limited operator is voluntary
- Prior to the procedure, advise patients of reproductive age about the potential risk of exposure during pregnancy