LMRT Radiobiology – In-Depth Breakdown

What is Radiobiology?

Radiobiology is the study of how ionizing radiation affects living tissue, especially at the cellular and molecular level.

- Focus: DNA damage, cell survival, and long-term effects
- Goal: Understand how to minimize harm while producing diagnostic images

Types of Radiation Interactions

Ionization

- Radiation removes electrons from atoms
- Creates ions → unstable → leads to damage

Excitation

- Electron is energized but not removed
- Less harmful than ionization

Mechanisms of Damage

Direct Action

- Radiation hits DNA directly

Causes:

- Single-strand breaks
- Double-strand breaks (most severe)

Indirect Action (MOST COMMON ~70%)

- Radiation interacts with water molecules
- Produces free radicals (OH^-)
- Free radicals damage DNA

DNA Damage Outcomes

- Repair (no damage)
- Misrepair (mutation)
- Cell death

Types of Effects:

- Somatic effects → affect the individual
- Genetic effects → passed to offspring

Radiation Effects

Deterministic Effects (Threshold-Based)

- Severity ↑ with dose
- Has a minimum threshold

Examples:

- Skin erythema
- Cataracts
- Radiation burns

Stochastic Effects (No Threshold)

- Probability ↑ with dose
- Severity does NOT depend on dose

Examples:

- Cancer
- Leukemia

Radiosensitivity (Law of Bergonié and Tribondeau)

Cells are more sensitive if they are:

- Rapidly dividing
- Undifferentiated
- Have a high metabolic rate

Most Sensitive:

- Bone marrow
- Reproductive cells
- GI lining

Least Sensitive:

- Muscle
- Nerve cells

Dose-Response Relationships

Linear No-Threshold (LNT)

- Even small doses carry risk
- Used in radiation protection

ALARA Principle
As Low As Reasonably Achievable
3 Key Factors:
Time
- Minimize exposure time

Distance
- Follow Inverse Square Law
- Doubling distance = ¼ exposure

Shielding
- Lead aprons (0.5 mm Pb)
- Thyroid shields
- Lead barriers

Inverse Square Law
- Intensity decreases as distance increases
- Critical for protecting technologists

Occupational Dose Limits (NCRP Guidelines)
- Whole body: 50 mSv/year (5 rem)
- Lens of eye: 150 mSv/year
- Skin/extremities: 500 mSv/year

Pregnant Worker:
- Fetus limit: 5 mSv total
- Monthly: 0.5 mSv

Patient Protection
Shielding
- Gonadal shielding (when applicable)
- Thyroid shielding

Beam Restriction
- Collimation reduces dose & scatter

Exposure Factors
- Use high kVp, low mAs when appropriate
- Avoid repeats

Scatter Radiation

- Main source of exposure to technologists
- Comes from patient interaction

Controlled by:

- Collimation
- Distance
- Shielding

Radiation Monitoring Devices

Types of Dosimeters:

- Film badge
- TLD (Thermoluminescent Dosimeter)
- OSL (Optically Stimulated Luminescence)

Rules:

- Wear at collar level (outside apron)
- Do NOT share
- Change regularly

Equipment Safety

- Proper filtration removes low-energy photons
- Collimator alignment is critical
- Regular equipment inspection required

Special Considerations

Pediatric Patients

- More radiosensitive
- Use lowest possible dose

Pregnant Patients

- Verify pregnancy status
- Shield abdomen when possible
- Avoid unnecessary exposure

****Indirect damage = most common**
****Double-strand DNA break = most severe**
****Stochastic = cancer risk**
****Deterministic = threshold + severity increases**
****Distance is the BEST protection for techs**
****ALARA ALWAYS applies**

Threshold vs Non-Threshold Effects (CRITICAL CONCEPT)

Deterministic Effects (Threshold Effects)

Definition: Effects that only occur after a certain radiation dose is reached (the *threshold*). Below that level, no effect is observed

Key Characteristics:

- There IS a minimum dose required before damage appears
- Severity increases as dose increases
- Usually involve large numbers of cells being damaged or killed

Examples & Approximate Thresholds:

- Skin erythema: ~2 Gy
- Cataracts: ~0.5 Gy (lens is very sensitive)
- Epilation (hair loss): ~3 Gy
- Radiation burns: higher doses

Why threshold exists:

- The body can repair small amounts of damage
- Once damage exceeds repair capability → visible injury occurs

Stochastic Effects (Non-Threshold Effects)

Definition: Effects that can occur at ANY dose level, even very small ones.

Key Characteristics:

- NO threshold (zero dose = zero risk, but any dose >0 carries some risk)
- Probability increases with dose
- Severity does NOT increase with dose
- Caused by cell mutation, not cell death

Examples:

- Cancer
- Leukemia
- Genetic mutations

Key Differences

Feature	**Threshold (Deterministic)**	**Non-Threshold (Stochastic)**
Dose requirement	Has threshold	No threshold
Severity	Increases with dose	Not dose-dependent
Probability	Increases after threshold	Increases with dose
Onset	Early	Late (years)
Cell damage	Massive cell death	DNA mutation
Examples	Burns, cataracts	Cancer, genetic effects

Easy Way to Remember

- **Threshold = "There's a limit before it starts"**
- **Non-threshold = "Any dose can cause it"**

Film Badge Dosimeter

How it works:

- Uses photographic film
- Radiation exposure darkens the film → measured later

Advantages:

- Cheap
- Provides permanent record

Disadvantages:

- Sensitive to heat & humidity
- Must be processed regularly
- Less accurate at low doses

Best Use:

- Basic monitoring (older technology)

TLD (Thermoluminescent Dosimeter)

How it works:

- Contains crystals (e.g., lithium fluoride)
- Radiation excites electrons → stored energy
- When heated → releases light proportional to dose

Advantages:

- More accurate than film
- Reusable
- Not affected by heat/humidity

Disadvantages:

- No permanent visible record
- Requires specialized reading equipment

OSL (Optically Stimulated Luminescence)
How it works:
- Uses aluminum oxide crystals
- Radiation traps energy
- Laser light releases stored energy → emits light → measured

Advantages:
- VERY sensitive (detects low doses)
- Can be reanalyzed multiple times
- Most modern & commonly used

Disadvantages:
- More expensive

Pocket Dosimeter (Self-Reading)
How it works:
- Small ionization chamber
- Provides instant reading

Advantages:
- Immediate dose reading
- Useful in high-exposure environments

Disadvantages:
- Easily damaged
- Less accurate long-term
- No permanent record

Electronic Personal Dosimeter (EPD)
How it works:
- Digital device measuring real-time exposure

Advantages:
- Real-time monitoring
- Alarm for high exposure

Disadvantages:
- Expensive
- Requires batteries

Pregnant workers: second badge at waist under apron

Occupational Dose Limits (Detailed Breakdown)
Based on guidelines from National Council on Radiation Protection and Measurements

Annual Occupational Limits

Area	Limit
Whole body	50 mSv (5 rem)
Lens of eye	150 mSv (15 rem)
Skin/extremities	500 mSv (50 rem)

Declared Pregnant Worker

Category	Limit
Entire pregnancy	5 mSv (0.5 rem)
Monthly limit	0.5 mSv (0.05 rem)

General Public

Category	Limit
Annual exposure	1 mSv (0.1 rem)

Dose Interpretation

Low Dose (<100 mSv)

- Effects are typically stochastic
- No immediate visible damage

Moderate Dose (100–1000 mSv)

- Increased cancer risk
- Possible mild biological effects

High Dose (>1 Sv / 1000 mSv)

- Deterministic effects begin
- Acute radiation syndrome possible

Acute Radiation Syndrome (ARS) Stages

- 1–2 Gy → mild symptoms
- 2–6 Gy → severe damage
- 6 Gy → often fatal

****Threshold = deterministic = severity increases**
****Non-threshold = stochastic = probability increases**
****OSL = most commonly used today**
****TLD = heat releases light**
****Whole body limit = 50 mSv/year**
****Pregnancy limit = 5 mSv total**
****Distance = MOST effective protection**