

Radiation Biology: Stochastic Effects of Radiation Exposure

Bushong, Chapter 34

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Late Effects

- ❑ Because the damage produced by radiation is manifest over long periods of time, the resultant damage is termed “Late Effects”
- ❑ May remain dormant for many years
- ❑ May never manifest in the exposed individual
- ❑ These are referred to as stochastic effects
 - ❑ The probability of a long-term effect taking place

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Late Effects

- ❑ Two categories of late effects:
 - ❑ Somatic effects
 - ❑ Occurring in the exposed individual (or fetus)
 - ❑ Genetic effects
 - ❑ Observed in succeeding generations

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Late Effects

- Stochastic
- Non-threshold effects
- Random
- Any increase in dose increases the **probability** of an effect (NOT severity)

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Late Effects

- Deterministic
- Have a threshold for effects
 - Below a certain dose, damage is not observed
 - Above a certain dose, **severity** of damage is increased

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Late Deterministic

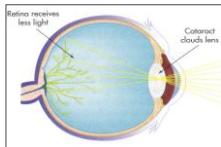
- Late deterministic somatic effects
 - Cataract formation**
 - Fibrosis
 - Organ atrophy
 - Loss of parenchymal cells
 - Reduced fertility**
 - Sterility**

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Late Deterministic

Cataractogenesis:

- A high probability of formation with a single dose of 2 Gy
- Results in partial loss of vision
- 15 year average latent period (varies from five to 30 years)
- Nonlinear, threshold model



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Late Stochastic

- Single most important somatic effect induced by radiation is carcinogenesis
- First reported case of radiation induced carcinoma was in 1902
- Within 15 years, there were 100 cases of skin cancer reported

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Risk Estimates

- While early effects of high dose radiation exposure are easily identifiable and measurable, late effects are more difficult to assess

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Human Data

- Sources of data for human exposures
 - Occupational exposure
 - Atomic Bomb survivors
 - Medical exposure
 - Fallout accidents in the Pacific Testing Grounds
- **** Experimental radiation is NOT conducted on humans

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Human Data

- Malignancies in which radiation has been implicated as a causative factor
 - Leukemia
 - Skin carcinoma
 - Osteosarcoma
 - Lung cancer
 - Thyroid cancer
 - Breast cancer

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In Utero Exposure

- Effects are time and dose related:
 - Prenatal death
 - Neonatal death
 - Congenital abnormalities
 - Malignancy induction
 - Impairment of growth
 - Mental retardation
 - Genetic effects

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Genetic Effects

- Impact of radiation on future generations
- All genetic information is stored in the DNA
- It has been shown that radiation exposure may damage or change the sequencing of the DNA (mutations)

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Genetic Effects

- There are “normal” spontaneous mutations unrelated to radiation exposure
 - The number of spontaneous mutations in each generation is termed mutation frequency
- The mutation frequency may be altered by mutagens
 - Viruses
 - Chemicals
 - Radiation

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Genetic Effects

- These mutations are “inheritable”
- Some mutations may be detrimental to life
- Some may lead to deformities or disease processes

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Doubling Dose

- The dose of radiation which ultimately doubles the mutation frequency
- Radiation has a linear effect on mutation frequency

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Doubling Dose

- The doubling dose for humans has been estimated at 1 Sv by the BEIR VII Committee (2005)
- In 2001 the United National Scientific Committee on the Effects of Atomic Radiation estimated the doubling dose in humans to be 1 Gy of sparsely ionizing low-dose radiation

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Life Span Shortening

- Chronically exposed individuals of low dose radiation die younger, than those not exposed
- Examination at death revealed:
 - A decrease in the numbers of parenchymal cells and blood vessels
 - An increase in connective tissue in organs (generally an indication of aging)
 - It appears that radiation may accelerate the aging process

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Cancer Induction

- ❑ **Radiation causes cancer**
- ❑ Controversy over dose (as low as 0.25 Gy)
- ❑ Doses much lower can induce malignancies in utero
- ❑ Infants and children more radiosensitive
- ❑ Latent periods vary with different types of cancer
 - ❑ Five to 30 years
 - ❑ For leukemia, seven to 12 years, but risk returns to normal after 20 years

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In Summary

- ❑ Late effects can be a result of high doses and low doses
- ❑ Three major types of late somatic effects
 - ❑ Cataractogenesis: deterministic
 - ❑ Embryologic (birth defects) and carcinogenesis: stochastic
- ❑ Radiation protection guidelines are based on the stochastic effects of radiation and on the linear, nonthreshold response

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