Radiobiological and Clinical Deterministic Effects of Ionizing Radiation Dose to Skin

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Christopher C. Nagle, MD, MPH, MS
ChrisNagleMD@RappWildernessMedicine.com
Wilderness Medicine, LLC
www.RappWildernessMedicine.com

Disclosures

I have no conflicts of interest, commercial bias, or disclosures to make.

Outline

- Skin histology
- Radiobiological effects of skin irradiation
- Clinical effects of skin irradiation
- Management of radiation burn
- Cases

Skin Exposure Sources

- Hot particles—fission products, e.g. Sr/Y-90
- External beams, e.g. x-ray accelerators
- Sealed sources, nuclear fuel rods
- Liquid, e.g. I-131

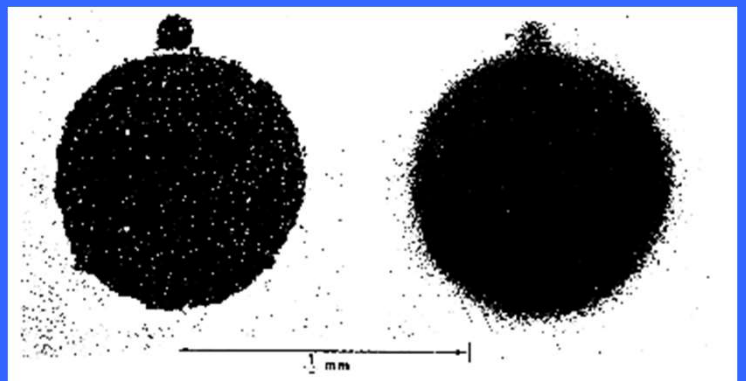


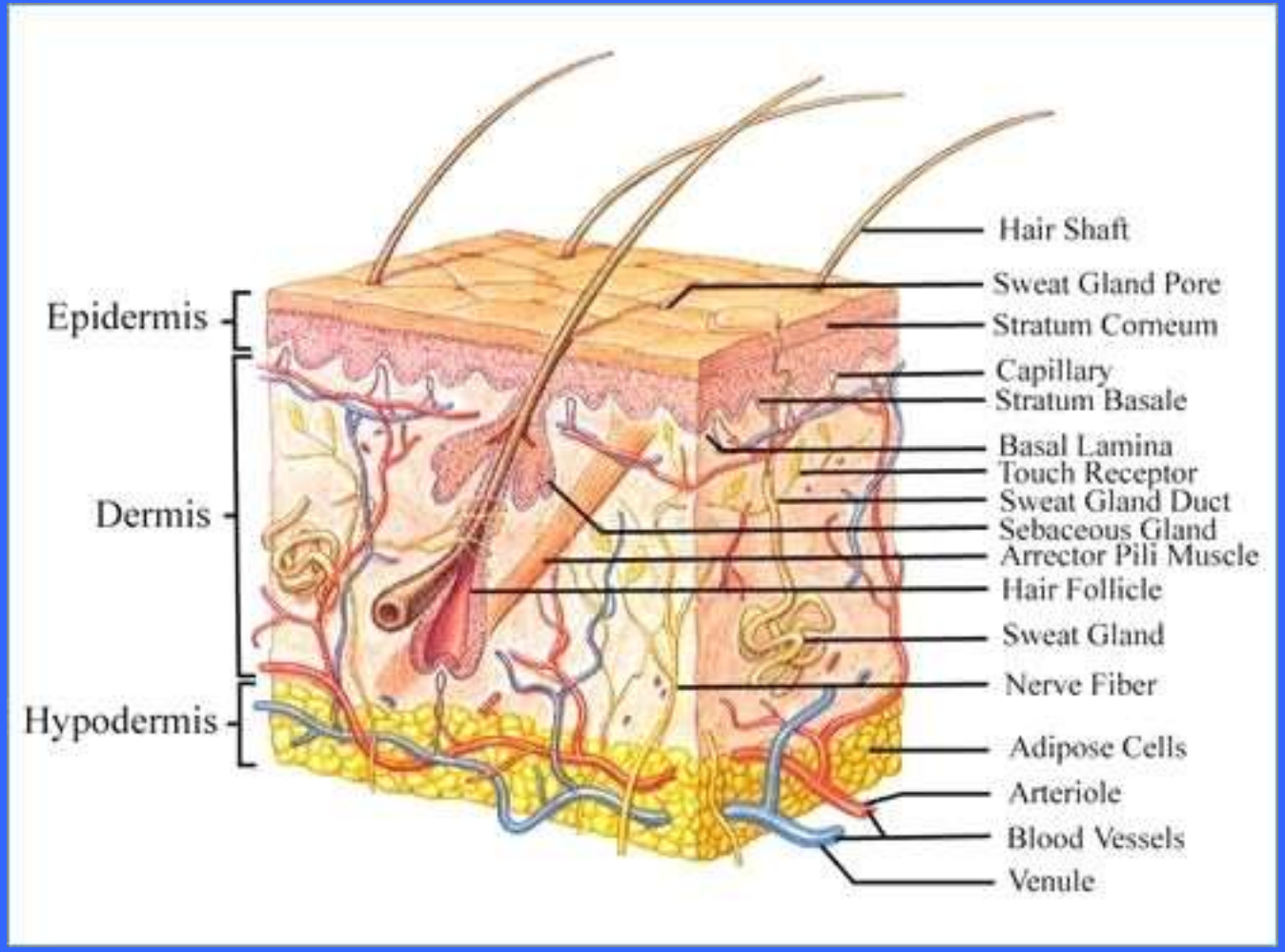
Fig. 2 Thin Section and Radioautograph of a Fallout Particle. It consists of iron oxide (magnetite). The radioactivity is distributed homogeneously throughout the particle.

RADIOLOGICAL AND NUCLEAR ACCIDENTS RESULTING IN RADIATION INJURY

Area of application	Source, radionuclide	Part of body exposed	Possible number of persons injured
Industry			
Sterilization	Co-60, Cs-137	Whole body, hands	1–3
Radiography	Ir-192, Cs-137	Hands, other parts	1–10
Gauging	Ir-192, Cs-137	Hands, other parts	1–2
Medicine			
Diagnostics	X ray generators	Hands, face	1–10
Therapy	Co-60, Cs-137 and accelerators	Whole body, hands and other parts	1–10 (more in extremely rare cases)
Research	Broad spectrum of sources, including reactors	Hands, face, other parts	1–3 (more at research reactors)
Spent sources	Co-60, Cs-137 and others	Hands, other parts	1–20 (more in extremely rare cases)
Nuclear reactors	Cs-137, Sr-90 I-131 Pu-210	Whole body Thyroid gland Lung	1–500 (usually much less than the number of persons affected)

*Agency, Vienna 1998. Diagnosis and Treatment of Radiation Injuries, Safety Series Report No. 2, International Atomic Energy.

Skin Layers


Epidermis
Dermis
Hypodermis
Hair Shaft
Sweat Gland Pore
Stratum Corneum
Capillary
Stratum Basale
Basal Lamina
Touch Receptor
Sweat Gland Duct
Sebaceous Gland
Arrector Pili Muscle
Hair Follicle
Sweat Gland
Nerve Fiber
Adipose Cells
Arteriole
Blood Vessels
Venule

EPIDERMIS

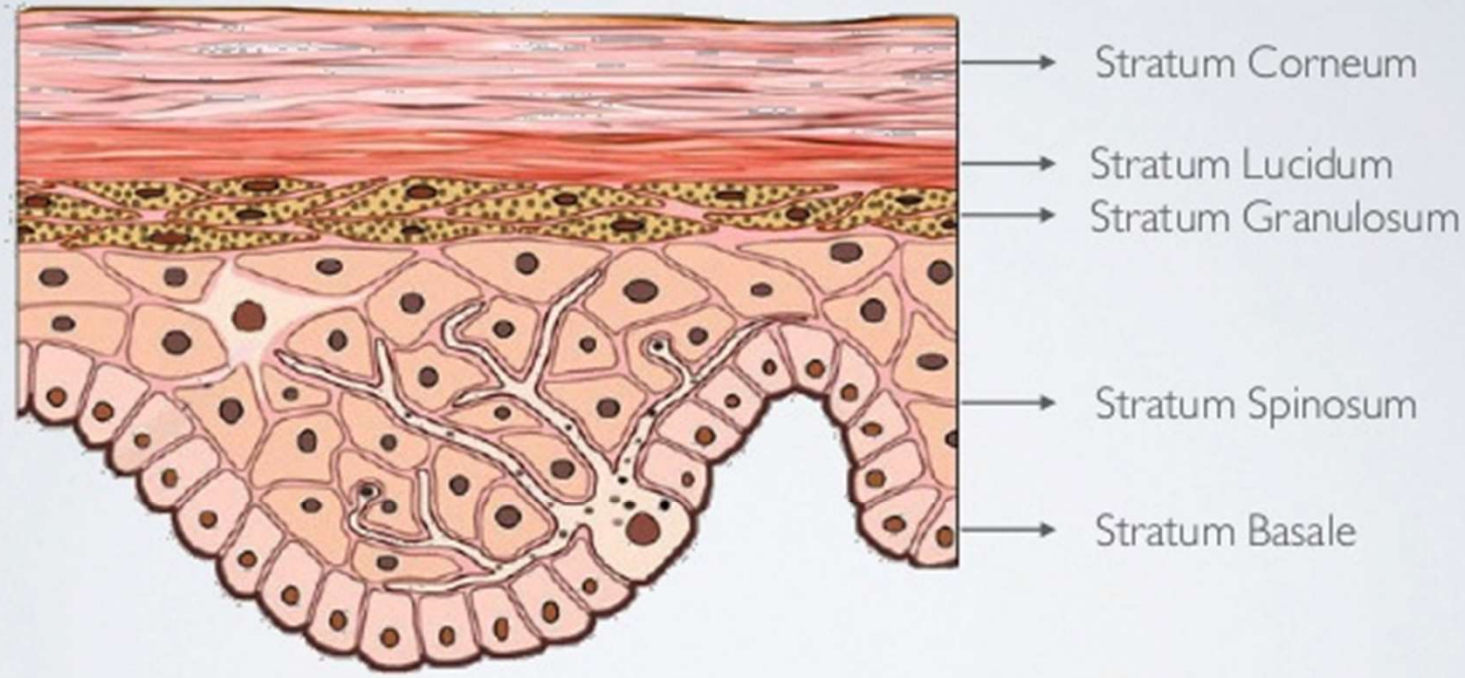
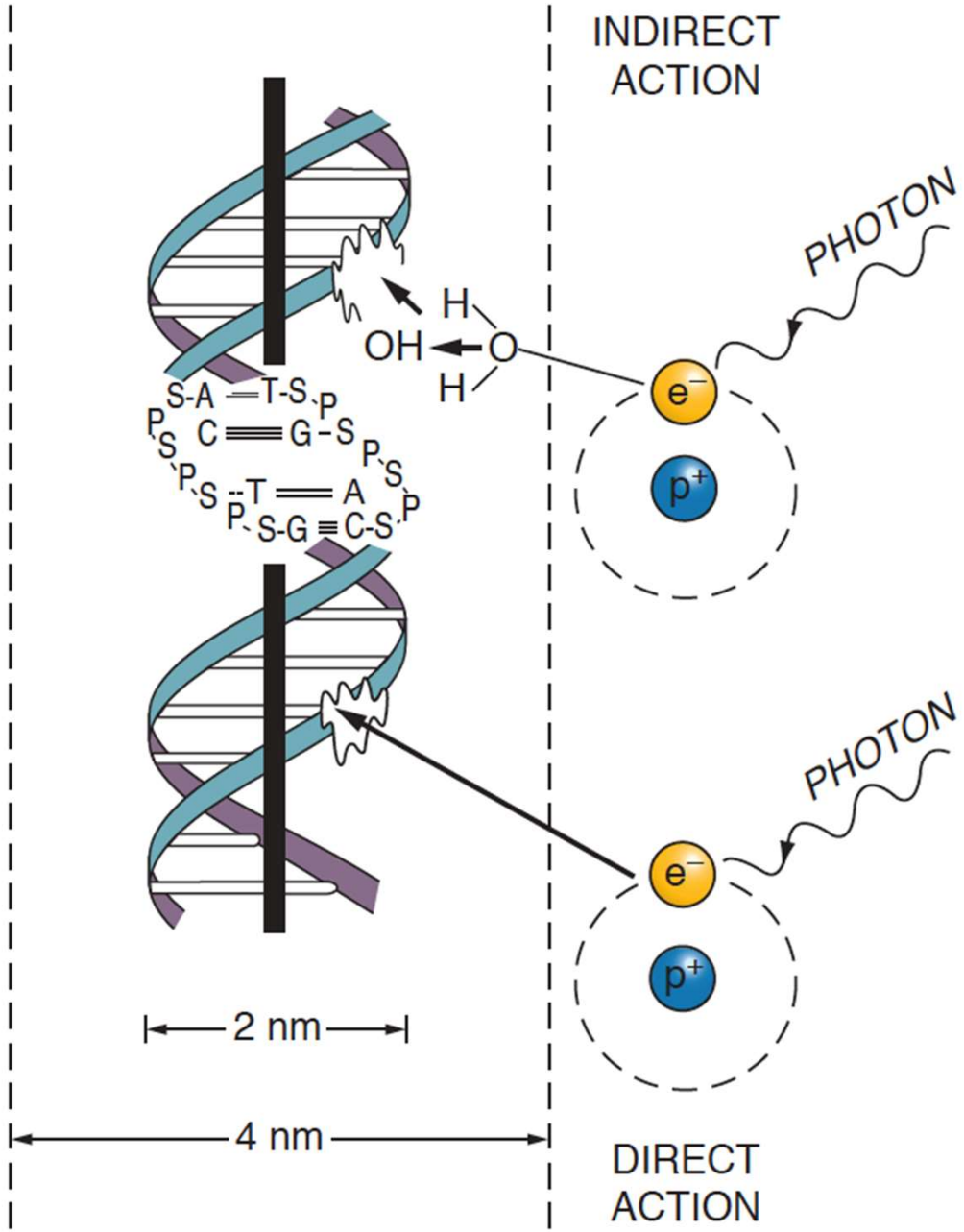


Image source: suggestkeyword.com

Radiation Injury

- Stochastic Effects
  - probabilistic, no known threshold
  - e.g. cancer
- Non-Stochastic Effects
  - deterministic, threshold of effect
  - e.g. cataracts



*Hall, Eric and Garcia, Amata. Radiobiology for the Radiologist. Philadelphia: Lippincott Williams & Wilkins, 2012.

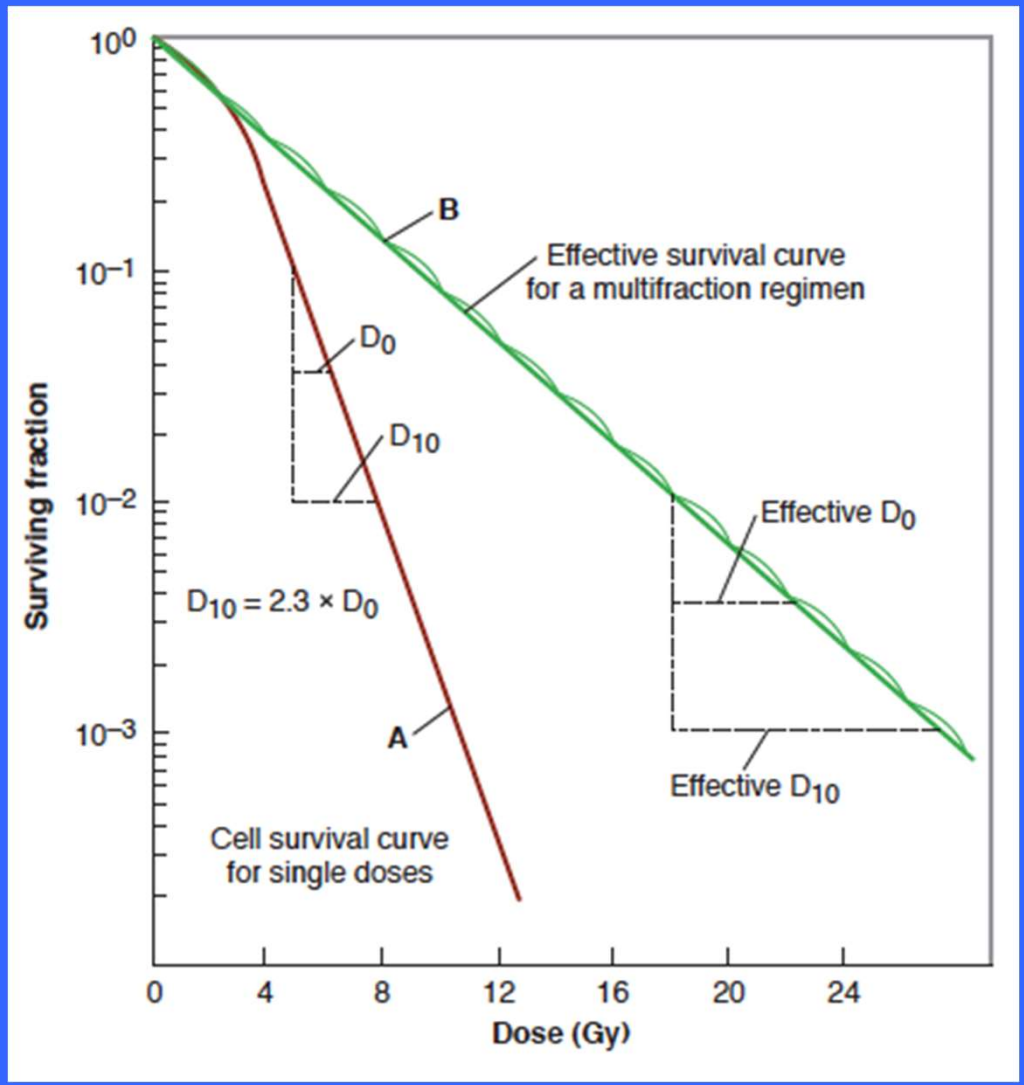
DNA Damage

Direct Damage

Indirect Damage

Base Nucleotide Damage
Single Strand Breaks
Double Strand Breaks

Fractionation/Dose Rate Effect



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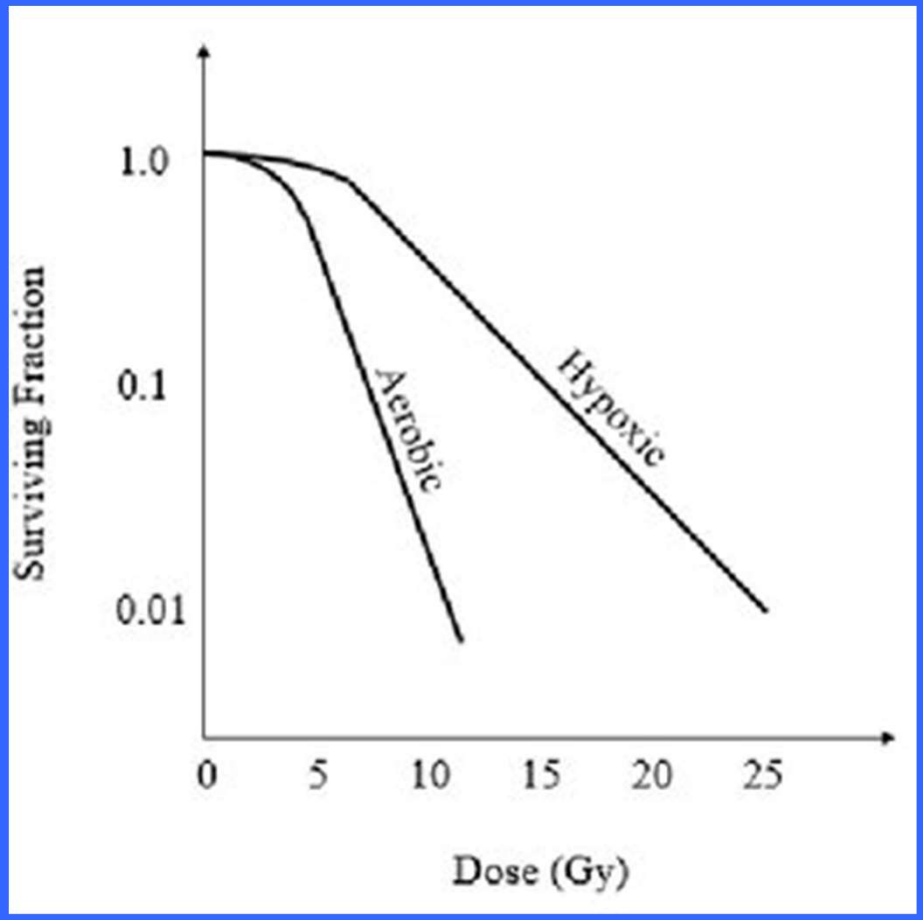
Oxygen Effect



Skin Inflammatory Reaction

Cascade of inflammatory mediators released:

- IL-1
- IL-6
- IL-8
- TNF-alpha
- TGF-beta
- Eotaxin

Induction of receptor expression on endothelial cells and keratinocytes
Mast cell activation

↓

Dilation of capillaries
Increased vascular permeability

↓

Recruitment of inflammatory cells (eosinophils, granulocytes)

↓

Diminished mitotic activity of basal cells

↓

Vasculitis of dermal veinules and arterioles

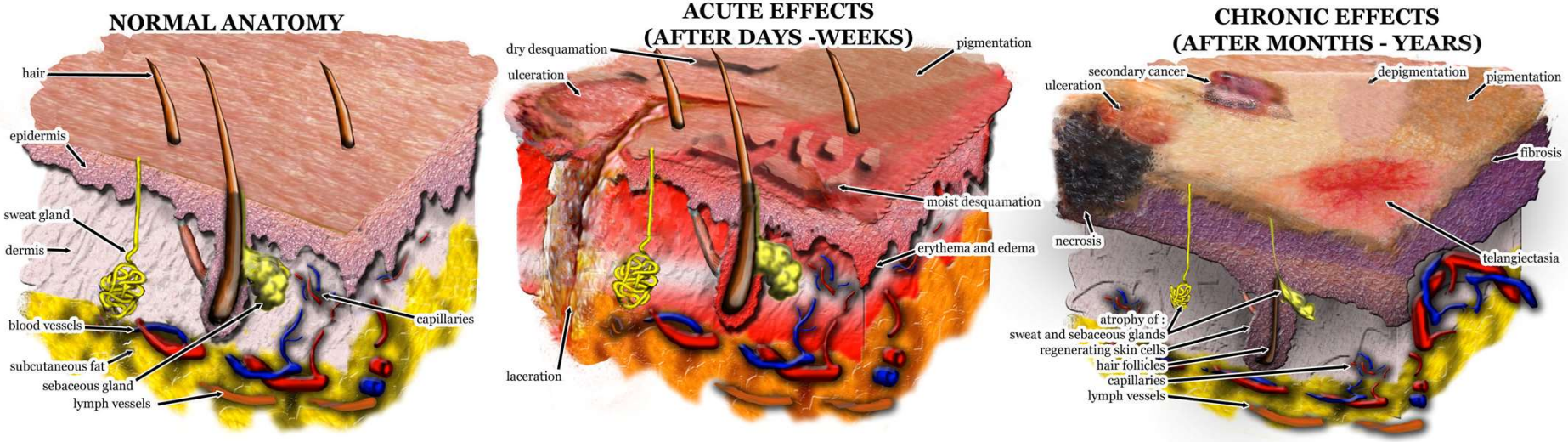
Symptoms/Signs of Cutaneous Radiation Injury

- Burning, itching, tingling
- Pain
- Edema
- Bleeding
- Epilation
- Acute Radiation Sickness (ARS) depending on dose/depth

Clinical Stages of Radiation Injuries

	Latency	Persistence
• Prodromal	min-hours	hours
• Manifestation	weeks	weeks
• Sub-acute	weeks	months
• Chronic	years	unlimited
• Late	years	unlimited

COMMON EFFECTS OF IONIZING RADIATION ON THE SKIN



Deterministic Acute Skin Effects

- Grade 1: erythema
- Grade 2: dry desquamation
- Grade 3: moist desquamation
- Grade 4: necrosis

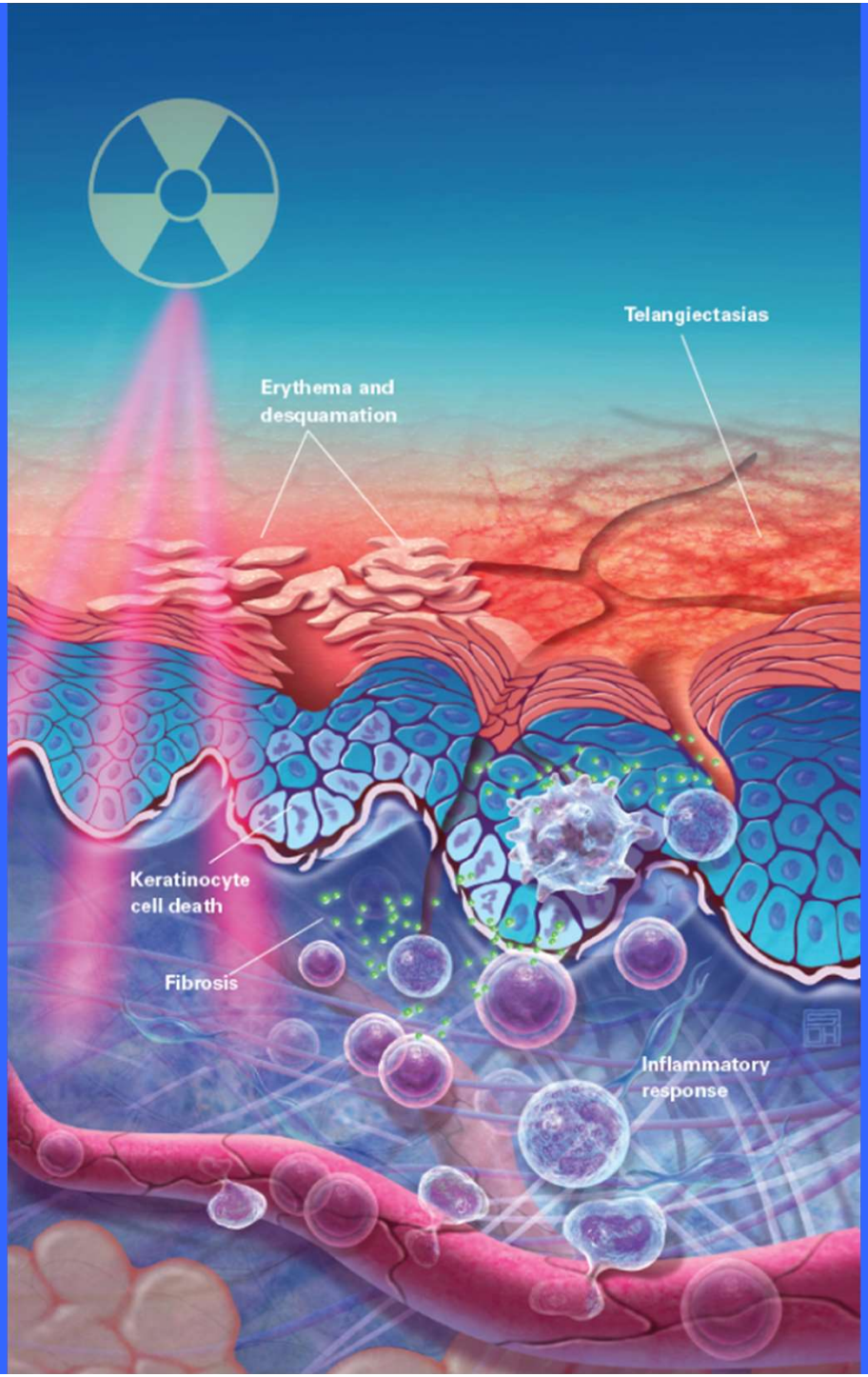
Diagnostics Aids to Grading the Extent of Skin Involvement

Non-Invasive

- Sonography (7.5–20 MHz) Histology
- Thermography Skin biopsies
- Capillary microscopy
- Dermatoscopy
- Profilometry
- Magnetic resonance imaging
- Bone scintigraphy

Invasive

- Skin Biopsy—histology


Telangiectasias
Erythema and
desquamation
Keratinocyte
cell death
Fibrosis
Inflammatory
response

Acute skin reactions

Acute skin changes with localized radiation dose

Acute skin effect	Dose (Gy)	Onset
Early transient erythema	2	Hours
Faint erythema; epilation	6–10	7–10 Days
Definite erythema; hyperpigmenation	12–20	2–3 Weeks
Dry desquamation	20–25	3–4 Weeks
Moist desquamation	30–40	4 Weeks
Ulceration	>40	6 Weeks

*Radiotherapy induced Skin reactions. Radiation Oncology. August 06, 2015.

Factors Impacting Acute Skin Effects

- Fractionation of dose
- Total time of delivery of dose
- Particular area of body
- Comorbidities/Adverse health behaviors

Delayed Skin Effects

- Necrosis
- Ulceration
- Fibrosis
- Telangiectasia's

Management of Acute Exposure

- Prevention—Time, Distance, Shielding
- ALARA principle
- Dosimetry

Management of Acute Exposure

Conservative

- Cleanse skin
- Control pain/provide comfort
- Avoid friction/trauma
- Cooling locally
- Prevent infection
- Medications
- Hyperbaric oxygen therapy

Surgical

- Dosimetry-guided wide excision
- Full and partial thickness grafting
- Flap creation
- Amputation

Medication Management

- Antibiotics (oral and topical)
- Antihistamines (e.g., diphenhydramine, hydroxyzine)
- Corticosteroids (e.g. prednisone, methyl-prednisolone)
- Anti-oxidant vitamins A, C, E
- Pentoxifylline
- Superoxide-dismutase

Mesenchymal Stem Cell (MSC) Injection

- Multi-potent cells
- Injected directly into involved skin
- Derived from bone marrow
- Marked improvement of wound healing

Cases

Questions???