Skin injuries in interventional procedures

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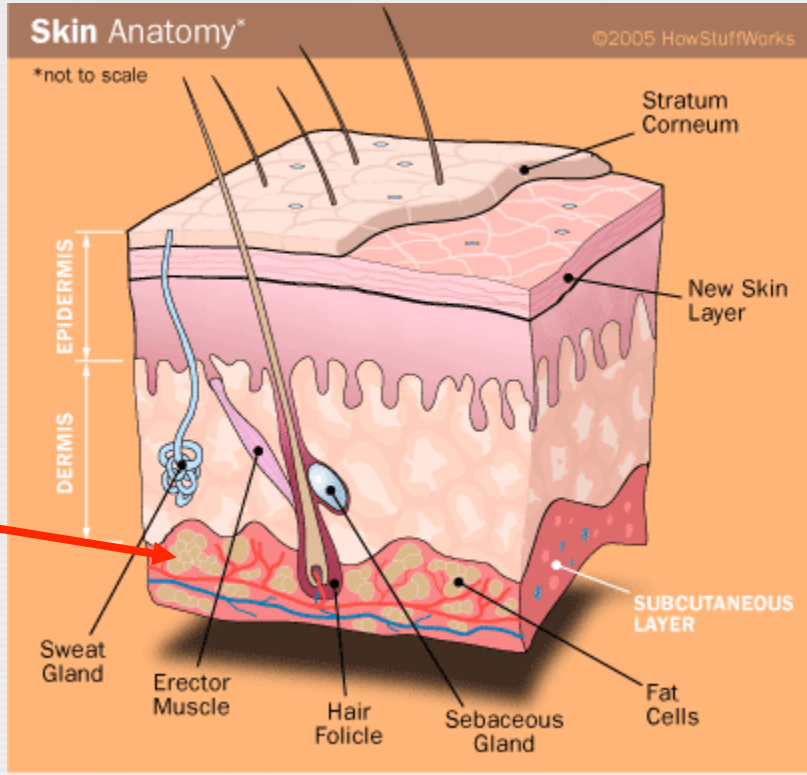
Skin injury

- Although called skin injury severe injuries can extend upto subcutaneous fat and muscle
- Epidermis
- Dermis
- Subcutaneous tissue



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Radiology

Fluoroscopically Guided Interventional Procedures:

A Review of Radiation Effects on Patients' Skin and Hair[1]

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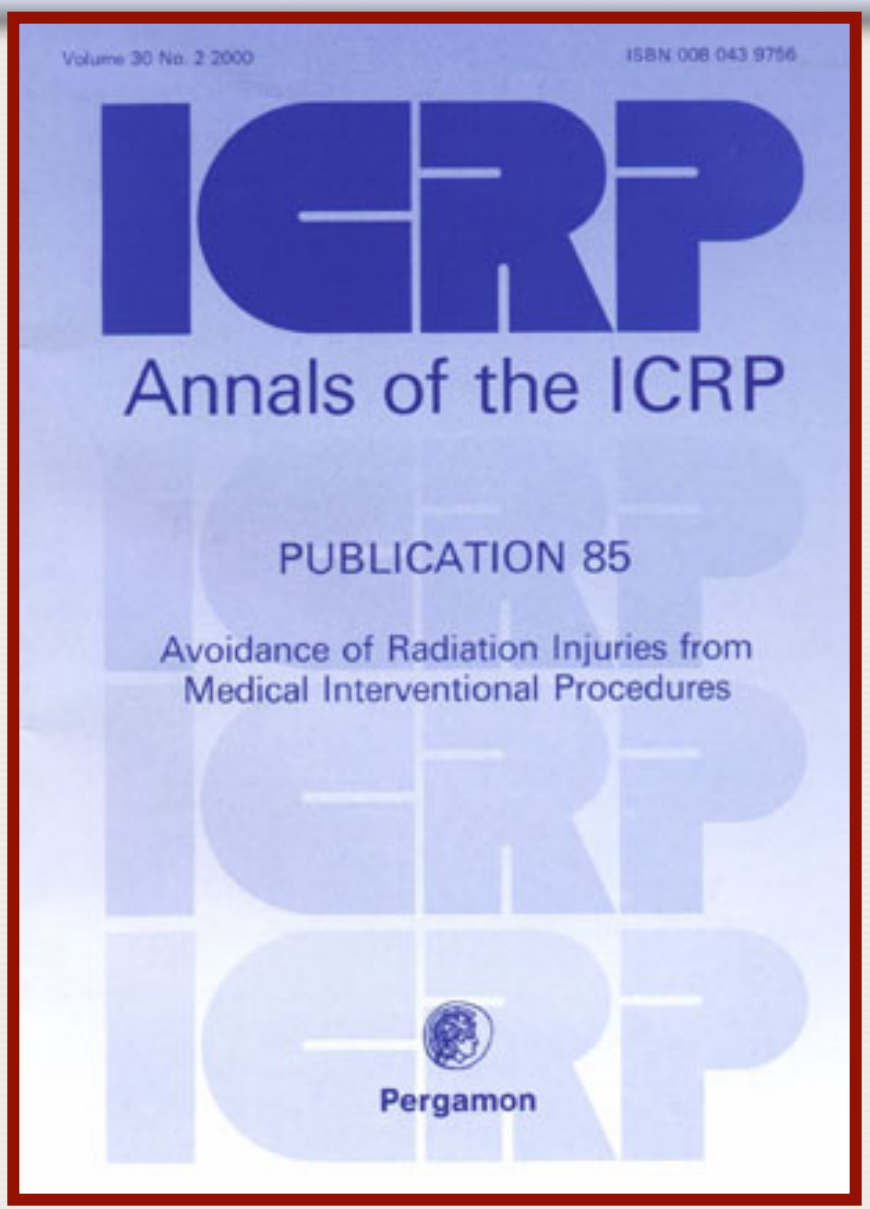
Most advice currently available with regard to fluoroscopic skin reactions is based on a table published in 1994. Many caveats in that report were not included in later reproductions, and subsequent research has yielded additional insights. This review is a consensus report of current scientific data. Expected skin reactions for an average patient are presented in tabular form as a function of peak skin dose and time after irradiation. The text and table indicate the variability of reactions in different patients. Images of injuries to skin and underlying tissues in patients and animals are provided and are categorized according to the National Cancer Institute skin toxicity scale, offering a basis for describing cutaneous radiation reactions in interventional fluoroscopy and quantifying their clinical severity. For a single procedure performed in most individuals, noticeable skin changes are observed approximately 1 month after a peak skin dose exceeding several grays. The degree of injury to skin and subcutaneous tissue increases with dose. Specialized wound care may be



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Factors that affect skin injury

- Radiation dose
- Interval between irradiation (dose fractionation)
- Size of skin area irradiated

- Biological factors

Recognizing radiation injury and effects

Characteristics of radiation injury

Effect	Single dose Threshold (Gy)	Onset
Early transient erythema	2	Hours
Main Erythema	6	~10 d
Temporary hair loss	3	~3 wk
Permanent hair loss	7	~3 wk
Dry desquamation	14	~4 wk
Moist desquamation	18	~4 wk
Secondary ulceration	24	>6 wk
Late erythema	15	~6 – 10 wk
Ischemic dermal necrosis	18	>10 wk
Dermal atrophy (1st phase)	10	>14 wk
Dermal atrophy (2nd phase)	10	>1 yr
Induration (Invasive Fibrosis)	10	
Telangiectasia	10	>1 yr
Late dermal necrosis	>12?	>1 yr
Skin cancer	not known	>5 yr

Rigid adherence to any dose effect Table is UNWISE

Single delivery radiation dose to skin of neck, torso, pelvic, buttocks or arms, ~~NOT scalp~~

Band	Single-site acute skin-dose (Gy)	NCI Skin reaction grade
A1	0-2	NA
A2	2-5	1
B	5-10	1-2
C	10-15	2-3
D	>15	3-4

Doses are NOT rigid boundaries

Skin dosimetry is unlikely to be more accurate than ±50%

Figure A1: NCI skin toxicity grade 1. Two

Figure 5: NCI skin toxicity grade 2 (see Appendix).

Figure A5: NCI skin toxicity grade 3. Increased severity

a. b.

Figure A8: NCI skin toxicity grade 4. (a) Central area of deep necrosis surrounded by indurated and

Tissue Reactions from Single-Delivery Radiation Dose to Skin of the Neck, Torso, Pelvis, Buttocks, or Arms

Band	Single-Site Acute Skin-Dose Range (Gy)*	NCI Skin Reaction Grade†	Approximate Time of Onset of Effects			
			Prompt	Early	Midterm	Long Term
A1	0–2	NA	No observable effects expected	No observable effects expected	No observable effects expected	No observable effects expected
A2	2–5	1	Transient erythema	Epilation	Recovery from hair loss	No observable results expected
B	5–10	1–2	Transient erythema	Erythema, epilation	Recovery; at higher doses, prolonged erythema, permanent partial epilation	Recovery; at higher doses, dermal atrophy or induration
C	10–15	2–3	Transient erythema	Erythema, epilation; possible dry or moist desquamation; recovery from desquamation	Prolonged erythema; permanent epilation	Telangiectasia‡; dermal atrophy or induration; skin likely to be weak
D	>15	3–4	Transient erythema; after very high doses, edema and acute ulceration; long-term surgical intervention likely to be required	Erythema, epilation; moist desquamation	Dermal atrophy; secondary ulceration due to failure of moist desquamation to heal; surgical intervention likely to be required; at higher doses, dermal necrosis, surgical intervention likely to be required	Telangiectasia‡; dermal atrophy or induration; possible late skin breakdown;wound might be persistent and progress into a deeper lesion; surgical intervention likely to be required

Note.— Applicable to normal range of patient radiosensitivities in absence of mitigating or aggravating physical or clinical factors. Data do not apply to the skin of the scalp. Dose and time bands are not rigid boundaries. Signs and symptoms are expected to appear earlier as skin dose increases. Prompt is <2 weeks; early, 2–8 weeks; midterm, 6–52 weeks; long term, >40 weeks.

* Skin dose refers to actual skin dose (including backscatter). This quantity is not the reference point air kerma described by Food and Drug Administration (21 CFR § 1020.32 [2008]) or International Electrotechnical Commission (57). Skin dosimetry is unlikely to be more accurate than ± 50%. NA = not applicable.

† NCI = National Cancer Institute

‡ Refers to radiation-induced telangiectasia. Telangiectasia associated with area of initial moist desquamation or healing of ulceration may be present earlier.

NCI Skin toxicity

- **Grade 1**: faint to moderate erythema
- **Grade 2**: moderate to brisk erythema; patchy moist desquamation, mostly confined to skin folds and creases; and moderate edema
- **Grade 3**: moist desquamation in areas other than skin folds and creases
- **Grade 4**: Skin necrosis or ulceration of full-thickness dermis and spontaneous bleeding from involved site

Factors that affect skin injury

- Radiation dose
- Interval between irradiation (dose fractionation)
- Size of skin area irradiated

- Biological factors

Exposure in multiple sessions

- If there is no overlap of entrance beam from different exposure, each session can be considered separate
- A conservative approach to multiple radiation exposure of the same portion is to assume that there is no repair of sublethal DNA damage
- Resulting over estimate- safety margin

Exposure in multiple sessions

- If the second procedure is likely to irradiate same part of the skin:
  - Increase time between two exposures
  - Examine skin before starting the procedure
- Previously irradiated skin often looks normal, but reacts abnormally when exposed to another insult

Balter et al. Radiology2010, 254, 326-341

procedures consisting of multiple sessions, the full procedure should not extend over more than 1–2 months because the model has only been applied to standard radiation therapy schedules within this time scale. Initially a reference point is established for single dose procedure using the following equation:

$$\mathrm{BED} = D\left(1+\frac{D}{\alpha/\beta}\right), \qquad \text{(E1)}$$

where BED is the biologically effective dose to which the likely effects of a more complex procedure have to be compared, D is the size of the dose from the single procedure, and α/β is a tissue-specific constant related to the survival characteristics of the cells in the tissue at risk. For late radiation damage to the skin, a value of 3–4 Gy is frequently applied (82,83).

For a complex procedure involving multiple sessions with 24 hours or more between each session, the total dose D in the simple equation (ie, Eq [E1]) is replaced by the dose received at each stage, d_1, d_2, d_3, such that

$$\mathrm{BED_m} = d_1\left(1+\frac{d_1}{\alpha/\beta}\right)+d_2\left(1+\frac{d_2}{\alpha/\beta}\right)+d_3\left(1+\frac{d_3}{\alpha/\beta}\right)\ldots. \qquad \text{(E2)}$$

When compared with the BED value, $\mathrm{BED_m}$ will indicate if the biologic effectiveness of the more complex procedure is similar to or higher or lower than what is considered acceptable for a single session. If necessary, the single dose equivalent can be calculated by substituting the value of $\mathrm{BED_m}$ into Equation (E1) and solving this for the new value of D.

Equation (E2) assumes the complete repair of sublethal damage between sessions. However, when two or more sessions are performed in one day there will be incomplete repair of sublethal damage between successive sessions, leading to

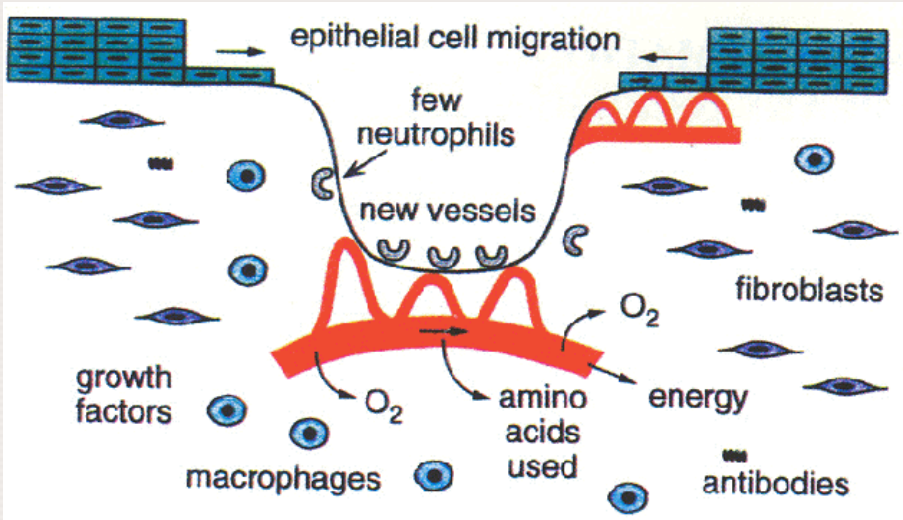
Factors that affect skin injury

- Radiation dose
- Interval between irradiation (dose fractionation)
- Size of skin area irradiated

- Biological factors

Size of irradiated area

- E.g. in RT mostly small fields
- If small area is irradiated: Will heal quickly, cell migration from neighboring skin
- Same reaction from same dose in large field will not heal quickly



Well-defined single dose clinical dose-response curves are not available for IR

Most data is from orthovoltage therapy and in pigs

Factors that affect skin injury

- Radiation dose
- Interval between irradiation (dose fractionation)
- Size of skin area irradiated

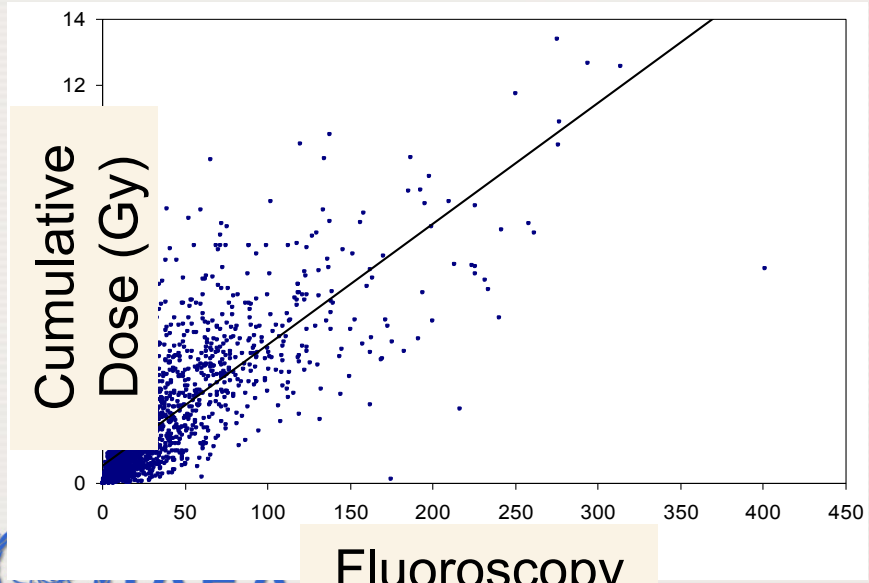
- Biological factors

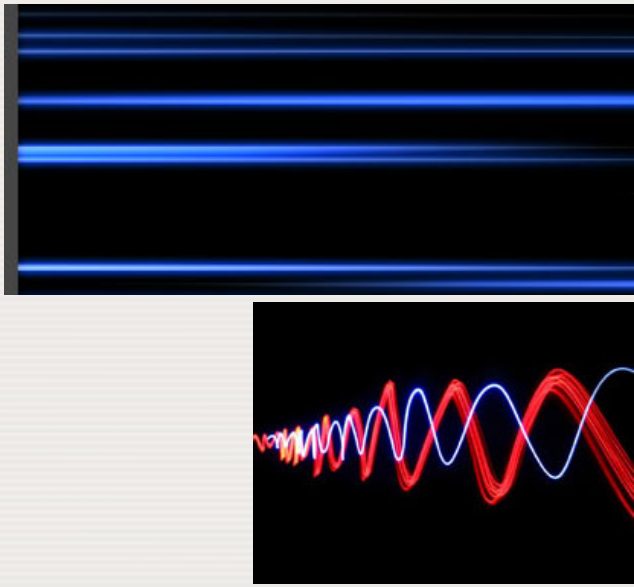
Biological Factors that influence skin reaction

- Patient related factors: Smoking, poor nutritional status, compromised skin integrity, obesity, overlapping skin folds,
  - Location of irradiated skin (anterior neck most sensitive, Less sensitive: flexor surface of extremities, trunk, back, nap of neck, scalp…in that order
  - Scalp is relatively resistant, but hair epilation in scalp occurs at lower doses as compared to hair at other parts
  - Individual with light colored skin are most sensitive

What Dose Quantity is Most Appropriate?

- ~~Effective dose~~
- ~~Organ dose~~
- Machine output- exposure rate: Not really
- ~~Fluoroscopy time~~

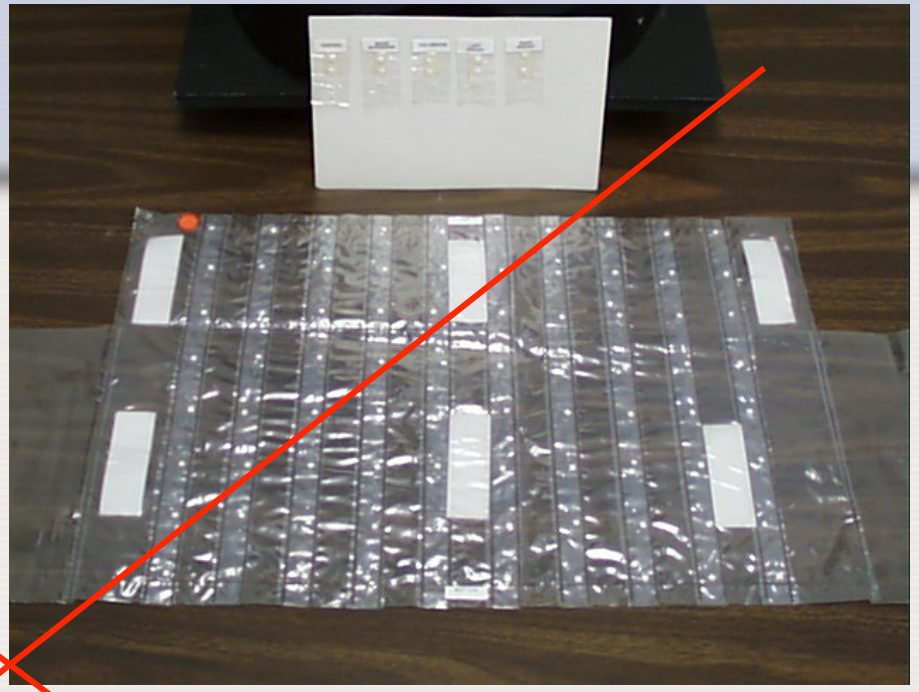




Fluoroscopic Time (FT)

- ~~Tables: Column indicating FT needed to cause radiation effect~~
- This can be misleading & dangerous
- FT is an extremely poor indicator of risk of skin injury
- FT should not be relied upon **as sole dose metric** for complex procedures
- It should be used with these understandings

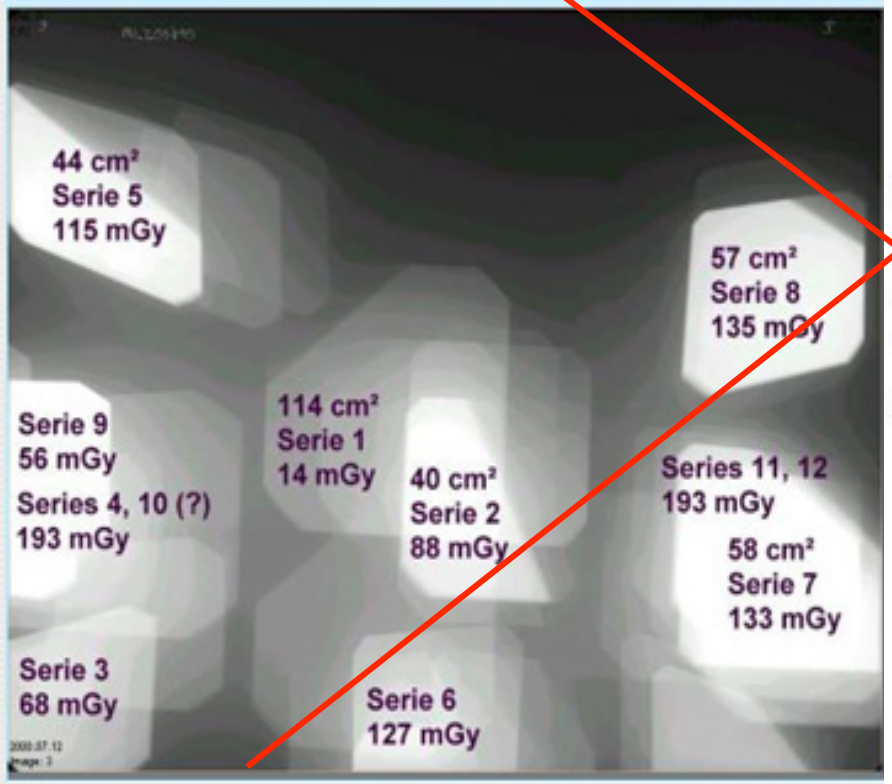
TLD grid

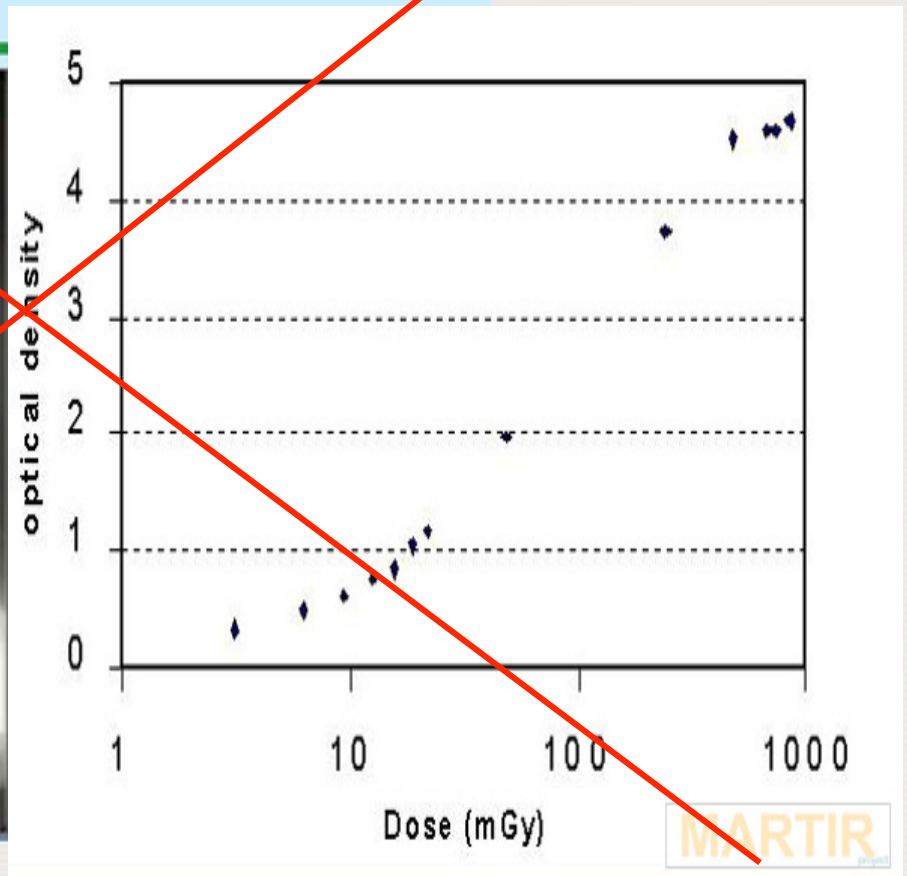


- 80 LiF TLD's
- Attached to polyethylene carrier
  - 8 x 10 chip matrix
  - 4 cm x 4 cm grid spacing
- Provide control TLD's

Methods using slow film

Slow film method (Vano E et al. Patient dosimetry in interventional radiology using slow film systems. Br J Radiol 1997; 70: 195-200)



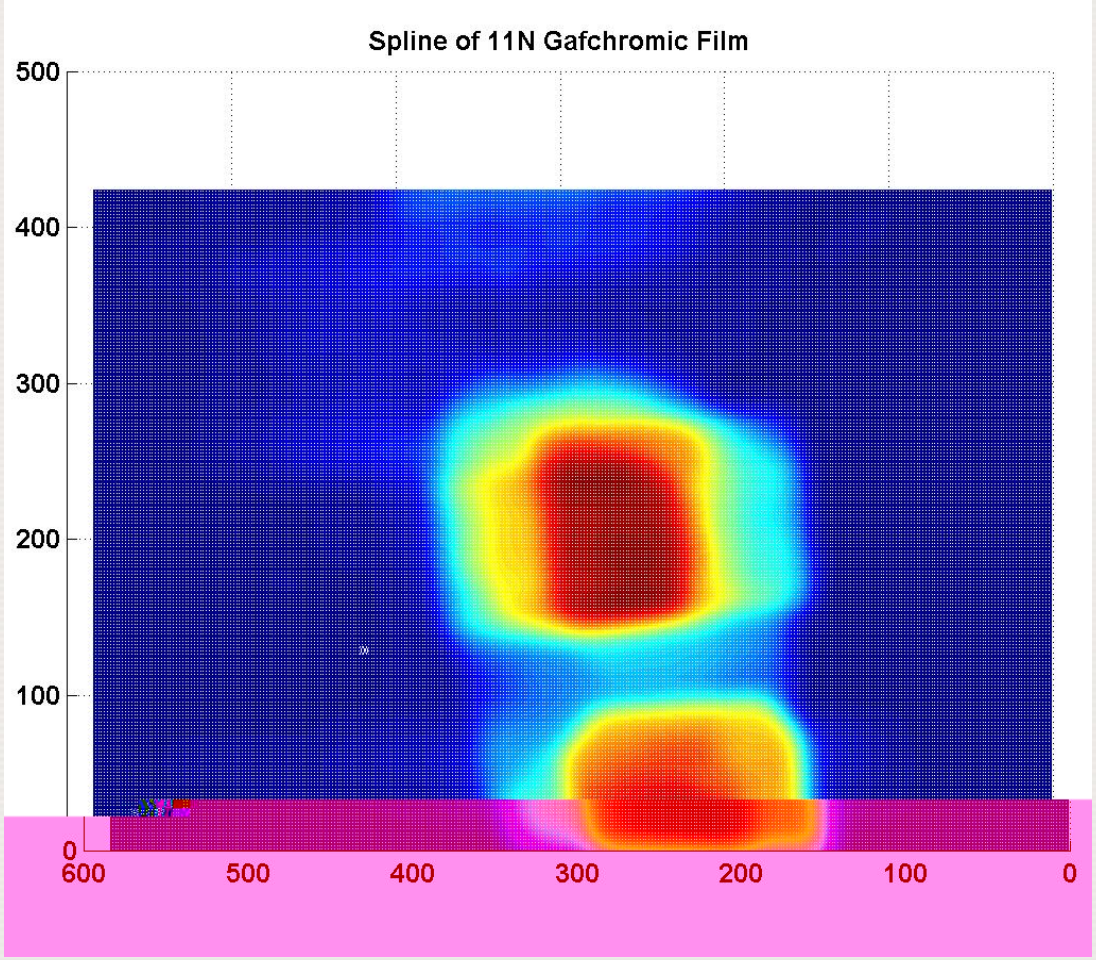


From MARTIR EC training programme (pub no. 199)
www.europa.eu.int/comm/environment/radprot/#news

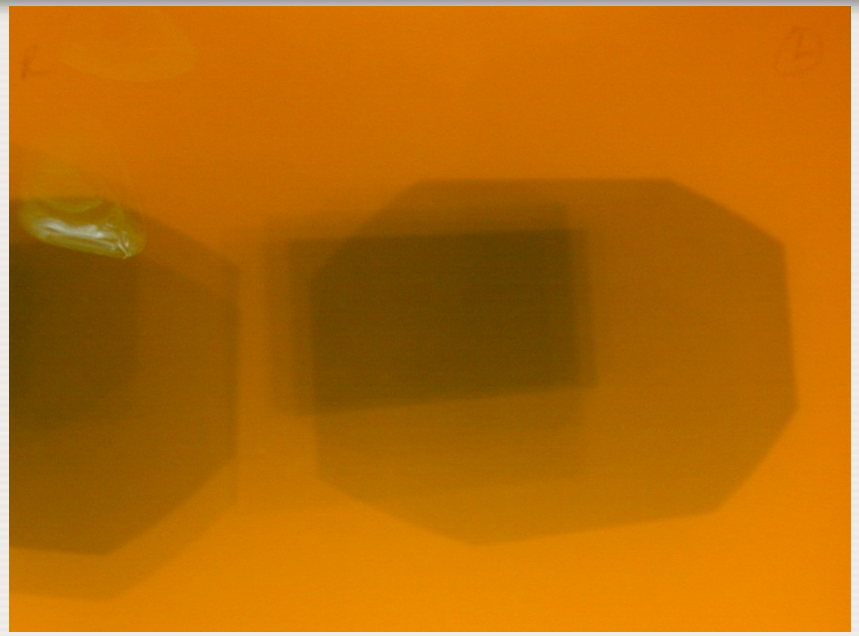
Radiochromic detectors

RADIOCHROMIC FILMS:

- Gafchromic XR Type R, usefull dose range: 0.1-15 Gy
- Minimal dependence on photon energy (60 - 120 keV)
- Acquisition: b/w, 12 bit/pixel image (with a flatbed scanner)



Peak skin dose



Example of dose distribution in a Coronary angiography procedure shown on a radiochromic film

√

BUT

- Expensive, each film ≈ $20
- Not for routine use

Alternative

Electronic methods- Machine can provide

- Dose at interventional reference point √
- Cumulative air kerma

Upcoming

- Computer estimated peak skin dose and dose plots based on machine rotation (views) exposure factors

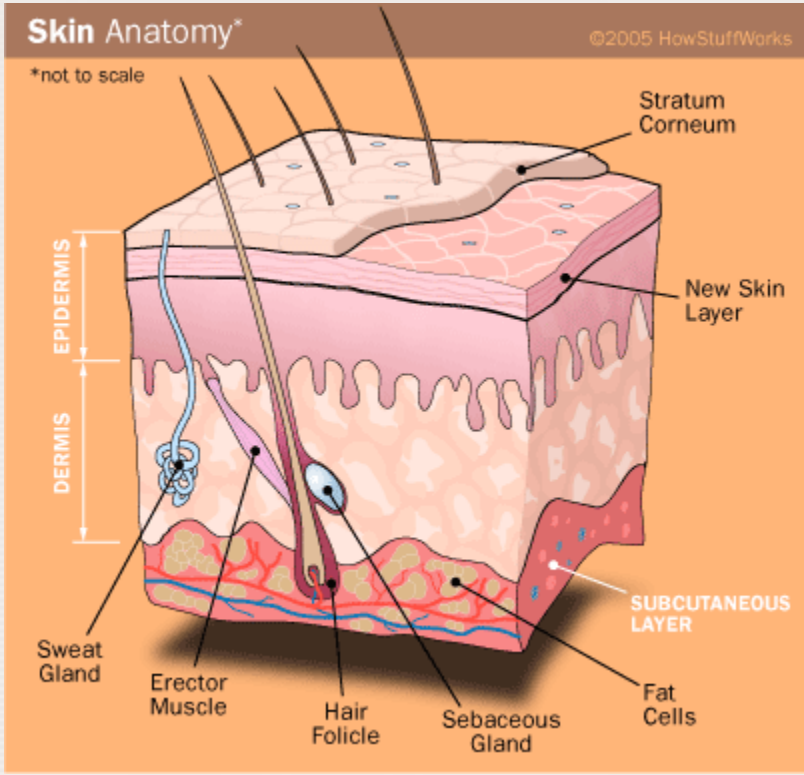
Dosimetry features in modern angiography equipment

- DAP/KAP: Gy.cm^2 or equivalent units
- Cumulative air kerma (Gy)- This can be related to peak skin dose (work in progress).

Management

Skin injury

- Although called skin injury severe injuries can extend upto subcutaneous fat and muscle



- **Reactions below 5 Gy or so are not a clinical problem as long as they are properly diagnosed.**
- **Once this is done, the patient almost never has any issues.**

Treatment of skin injury

- **Major injury-** can be Very Complex
- Combined skills of
  - Wound care specialist
  - Dermatologist
  - Plastic surgeon and others
  - Best guidance: Refer patients to experienced providers with all information on radiogenic origin
  - Invariably experience may not be available, so take foreign help. Email…. Makes things easier.

Sequence

- Dermatologist: Typically first to see
  - Dilemma:
    - He may not be aware
    - He is aware but patient does not know if the procedures he has undergone involves radiation, because interventionalist did not guide him
    - Diagnosis delayed for months

Cause of injury initially misidentified as pressure wound due to defibrillator pad.

Injury ascribed to defibrillator pads- sued company

Grounding electrodes used for electrocautery

Lesion required grafting.

Consequences of misdiagnosis

- Unnecessary dermatologic diagnostic procedures
  - Punch biopsy
  - Secondary complications

Ideal Situation- Diagnosis

- Patient undergoes complex procedure
- Skin dose > 5 Gy
- Patient asked to keep watch and get back
- Patient is called by hospital staff after 30 days
- No chance of missing case, it will lead to correct diagnosis

General Advice to Be Provided to Patients and Treating Physicians

Band	Skin Dose Range (Gy)	Advice to Patient
A1	0–2	No need to inform patient, because there should be no visible effects; if patient reports skin changes, then treat in response to the signs and symptoms
A2	2–5	Advise patient that erythema may be observed but should fade with time; Advise patient to call you if skin changes cause physical discomfort
B	5–10	Advise patient to perform self-examination or ask a partner to examine for skin effects from about 2 to 10 weeks after the procedure; tell patient where skin effects would most likely occur; if skin erythema and itching occur, patient should call radiologist's office; skin reactions are often treated conservatively; might advise patient to be examined by dermatologist or other treating physician and to inform treating physician that injury may be due to radiation; radiologist should also provide that physician with medical details of where the radiation-related skin effects are likely to occur
C	10–15	Medical follow-up is appropriate; advice is same as that for band B but also advise dermatologist or other treating physician that skin effects may be prolonged due to radiation dose and that prophylactic treatment for infection and monitoring of wound progression mat be required; pain could become a concern if doses were in the higher range of this band
D	>15	Medical follow-up is essential, nature and frequency of which depending on estimated radiation dose; advice is same as that for band C, but advise treating physician that the wound could progress to ulceration or necrosis

Note.—Applicable to normal range of patient radiosensitivities in the absence of mitigating or aggravating physical or clinical factors.

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NEW EMERGING CONCEPTS IN THE MEDICAL MANAGEMENT OF LOCAL RADIATION INJURY

MESENCHYMAL STEM CELL THERAPY FOR CUTANEOUS RADIATION SYNDROME

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Abstract—Systemic and local radiation injuries caused by nuclear power reactor accidents, therapeutic irradiation, or nuclear terrorism should be prevented or properly treated in order to improve wound management and save lives. Currently, regenerative surgical modalities should be attempted with temporal artificial dermis impregnated and sprayed with a local angiogenic factor such as basic fibroblast growth factor, and secondary reconstruction can be a candidate for demarcation and saving the donor morbidity. Human mesenchymal stem cells and adipose-derived stem cells, together with angiogenic and mitogenic factor of basic fibroblast growth factor and an artificial dermis, were applied over the excised irradiated skin defect and were tested for differentiation and local stimulation effects in the radiation-exposed wounds. The perforator flap and artificial dermal template with growth factor were successful for reconstruction in patients who were suf-

Key words: World Health Organization; exposure, radiation; radiation damage; radiotherapy

INTRODUCTION

THERE IS increasing worry regarding both systemic and local radiation injuries caused by nuclear power plant (NPP) reactor accidents, therapeutic irradiation for malignancy, interventional radiology (IVR) of unexpectedly prolonged fluoroscopic procedures for cardiovascular diseases such as arrhythmia or ischemic heart diseases, or nuclear medicine over-dose intakes of the radioactive material for internal radiation therapy. These conditions

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exposed. Local injuries appear as skin injuries; however, they may involve radiation damage to other organs and tissues. Local injuries evolve slowly over time and clinical signs and symptoms usually take days to weeks to manifest. Although in

handling of highly intense radioactive sources. The vast majority of local injuries are caused by sealed industrial sources, the most relevant of which are ^{60}Co, ^{90}Sr, ^{137}Cs,

Thank You

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