Safe Use of Radiation During Fluoroscopy Procedures

M A Cura MD, S. Castillo RN, M Hatab PhD, R Suri MD

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BAYLOR University Medical Center at Dallas

Purpose

Implement a program in the interventional radiology department to ensure safe use of radiation during interventional procedures.
Peak skin dose (PSD) is a measure of the likelihood of radiation-induced skin effects, for a variety of interventional radiology procedures.
The program intent to monitor and prevent procedures associated with unnecessary PSD greater than 2 Grays (Gy).

Aim Statement

To ensure that all patients' radiation exposure is below 2Gy for each fluoroscopy procedure.

Background

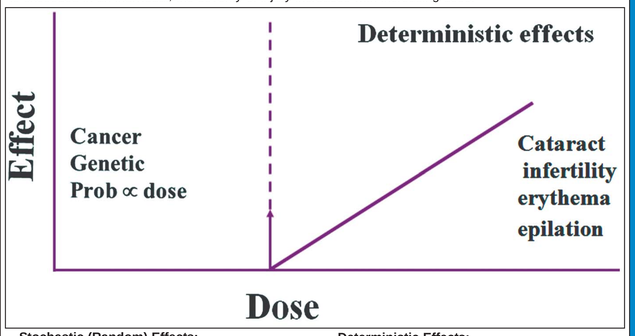
- Radiation:
  - ionizing energy can affect biologic tissues.
- Fluoroscopy:
  - real-time X ray imaging that is especially useful for guiding a variety of diagnostic and interventional procedures.
  - X ray exposure needed to produce one fluoroscopic image is low, complex fluoroscopic procedures requires large series of images and result in high exposures to patients.

Radiation

- **Air Kerma:** It is a measure of the amount of radiation energy, in the unit of joules (J), deposited or absorbed in a unit mass (kg) of air. It is expressed in the units of J/kg or grays (G).
- **Absorbed Dose:** is the energy imparted per unit mass by ionizing radiation to matter at a specified point. The SI unit of absorbed dose is the joule per kilogram. Absorbed dose is measured in Gray (Gy).
- **Effective Dose:** The sum, over specified tissues, of the products of the equivalent dose in a tissue and the tissue weighting factor for that tissue. Effective dose is measured in Sieverts (Sv). Stochastic risk factors are usually stated relative to effective dose.
- **Equivalent Dose:** takes into account the different probability of effects that occur with the same absorbed dose delivered by radiations with different radiation weighting factors. Effective dose is measured in Sv.
- **Peak Skin Dose (PSD):** The highest dose at any portion of a patient's skin during a procedure.
- **Fluoroscopy Time:** The total time that fluoroscopy is used during an imaging or interventional procedure.

Radiation Side Effects

- Stochastic Effect: A radiation effect whose probability of occurrence increases with increasing dose, but whose severity is independent of total dose.
- Deterministic Effect: A radiation effect characterized by a threshold dose. The effect is not observed unless the threshold dose is exceeded. (The threshold dose is subject to biologic variation.) Once the threshold dose is exceeded in an individual, the severity of injury increases with increasing dose.



Stochastic (Random) Effects:
- Cancer
- Mental Retardation
- Genetic Effects

Deterministic Effects:
- Sterility
- Cataracts
- Skin Erythema
- Hemopoietic Syndrome
- Gastrointestinal (GI) Syndrome
- Central Nervous System Syndrome

Radiation Dose Measurement

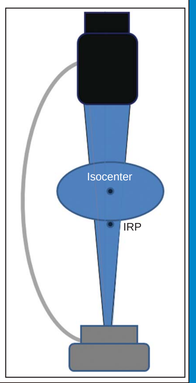
- Maximum local skin dose (MSD) or Peak Skin Dose (PSD): is the highest dose at any portion of a patient's skin during a procedure and is used to asses for Deterministic Effects.
- Dose–Area–Product (DAP): The integral of air kerma (absorbed dose to air) across the entire x-ray beam emitted from the x-ray tube. DAP is a surrogate measurement for the entire amount of energy delivered to the patient by the beam. DAP is measured in Gy-cm2 and used to asses for Stochastic (Random) Effects.

Factors that Increase Entrance Dose

Long duration of fluoroscopy
Use of high-intensity mode
Maintenance of a single angle of view
Obesity
Cranio-caudal angulation of the X-ray beam
High image magnification
No dose monitoring
X-ray machine defects

Methods to measure Peak skin dose (PSD) or Maximum local skin dose (MSD):

- **On-line methods:**
  - Point detectors (ion chamber, diode and Mosfet detectors)
  - Dose to Interventional Reference Point (IRP) via ion chamber or calculation
- **Off-line methods:**
  - Dose distribution is obtained with interpolation of point dose data (Large area detectors exposed during the procedure between tabletop and patient)
  - Area detectors: radiotherapy portal films, radiochromic films, TLD grid



On-line Methods

- Zinc-Cadmium based sensor, linked to a calibrated digital counter, is positioned on patient, in the X ray field.
- Real-time readout in mGy
- Point detectors (ion chamber, diode and Mosfet detectors)
- Cumulative Dose to Interventional Reference Point (IRP) via ion chamber or calculation
- Dose distribution calculated by the angio unit using all the geometric and radiographic parameters (C-arm angles, collimation, kV, mA, FIID, etc.)

Threshold Skin Entrance Doses for Different Skin Injuries

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

d: day(s), Gy: gray, wk: week(s), yr: year(s).

Effects of Radiation on Skin and Hair

Effect	Approximate Threshold (Gy)	Initial Occurrence	Note
Early transient erythema	2	Hours	Inflammation of the skin caused by activation of a proteolytic enzyme that increases the permeability of the capillaries
Acute ulceration	20	<2 weeks	Early loss of the epidermis that results from the death of fibroblasts and endothelial cells in interphase
Epilation	3	2 to 3 weeks	Hair loss caused by the depletion of matrix cells in the hair follicles; permanent at doses exceeding 6 Gy
Dry desquamation	8	3 to 6 weeks	Atypical keratinization of the skin caused by the reduction of the number of clonogenic cells within the basal layer of the epidermis
Main erythema	3	Days to weeks	Inflammation of the skin caused by hyperemia of the basal cells and subsequent epidermal hypoplasia
Moist desquamation	15	4 to 6 weeks	Loss of the epidermis caused by sterilization of a high proportion of clonogenic cells within the basal layer of the epidermis
Secondary ulceration	15	>6 weeks	Secondary damage to the dermis as a consequence of dehydration and infection when moist desquamation is severe and protracted
Late erythema	20	8 to 20 weeks	Inflammation of the skin caused by injury of the blood vessels; edema and impaired lymphatic clearance precede a reduction in blood flow
Dermal necrosis	20	>10 weeks	Necrosis of the dermal tissues as a consequence of vascular insufficiency
Invasive fibrosis	20	Months to years	Method of healing associated with acute ulceration, secondary ulceration, and dermal necrosis, leading to scar tissue formation
Dermal atrophy	10	>26 weeks	Thinning of the dermal tissues associated with the contraction of the previously irradiated area

Factors that may lower the threshold for radiation-induced skin injury

1. Previous radiation to the area

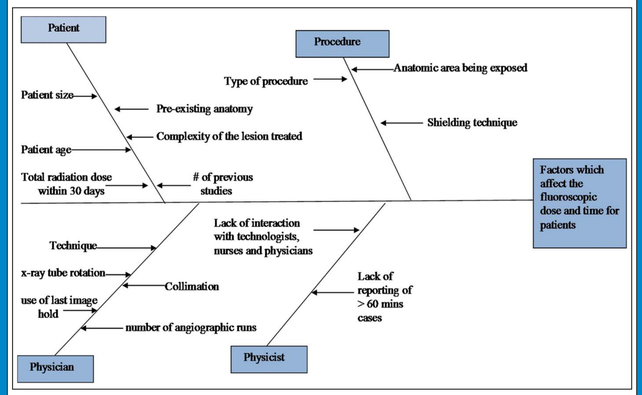
2. Diseases
- Diabetes mellitus
- Hyperthyroidism
- Collagen-vascular disease
- Ataxia telangiectasia

3. Drugs
- Actinomycin D
- Adriamycin
- Bleomycin
- Fluorouracil
- Methotrexate
- Simvastatin

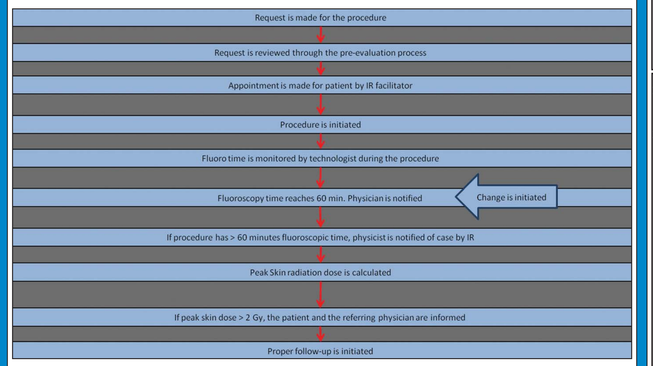
Methods

Initially an observational study was conducted. Prospectively demographic and radiation dose data was collected for subjects undergoing procedures in fluoroscopic suites equipped with built-in dosimetry capability. Subsequently a new quality improvement program was implemented. The program consisted of monitoring real time fluoroscopy time, notification to physician when fluoroscopy time reaches 50 minutes, education of dose reduction techniques, and establishing proper clinical follow-up of patients exposed to >2 Gy dose. It also included, one-to-one in-service with technologist, nurses and physicans concerning dose reduction, and active involvement of physicians in the prevention, recognition and management of radiation side-effects.

Fishbone



Pre-intervention Flow Chart



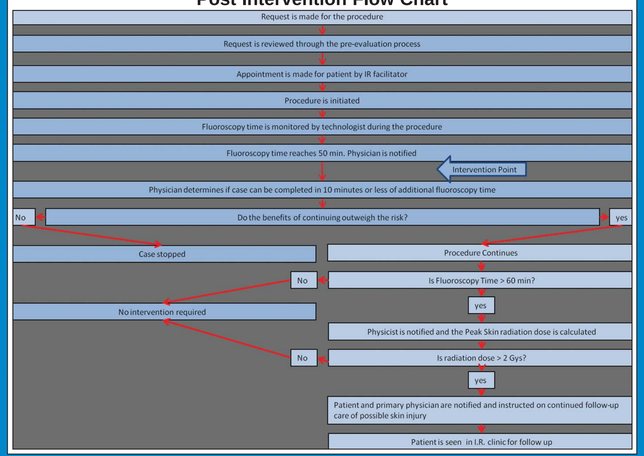
Intervention

- Monitoring real time fluoro time
- Notification to Physician of 50 minute flouro time
- Education of proper techniques of radiation use
- Establishing proper clinical follow-up of patients exposed to >2 Gy dose.

Implementing the Change

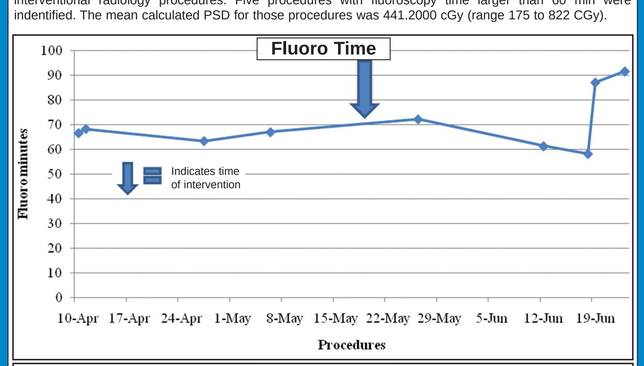
- Implemented new protocol for real time monitoring and notification by technologist during procedures.
- One-to-one in-services done with technologist concerning dose reaction
- Active involvement of physicians in the prevention, recognition and management of radiation side-effects.

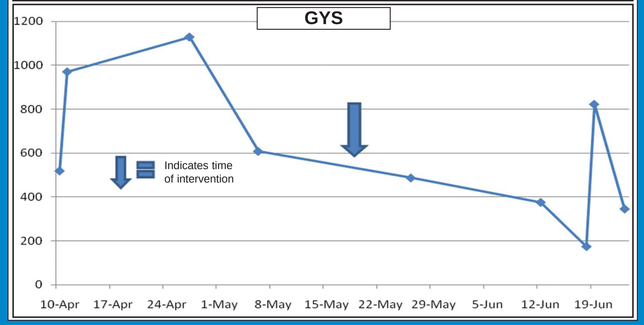
Post Intervention Flow Chart



Results

Over a 26 day period, fluoroscopy time data was recorded for all interventional radiology procedures. Four procedures with fluoroscopy time larger than 60 min were indentified. The mean calculated peak skin dose PSD for those procedures was 806.2500 centi-Gray units (cGy) (range 519 to 1128 cGy). After the quality improvement program was initiated, over a period of 110 days fluoroscopy time data was recorded for all interventional radiology procedures. Five procedures with fluoroscopy time larger than 60 min were indentified. The mean calculated PSD for those procedures was 441.2000 cGy (range 175 to 822 CGy).





Conclusion

Implementation of this new quality improvement program, did not increase the cost to the health institute or to the patient, was easily implemented into the current department procedures and can potentially prevent radiation induce injuries and recognize patient at risk of radiation exposure injuries and reduce any additional health care cost related to excessive use of radiation.

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