Safe use of Radiation during Fluoroscopy Procedures
The Team

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  – Radiology Technologist - Daryl Roberts, ARRT (R)
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• Sponsor Department
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  – Dr. Pam Otto – Director of Radiology, UHS
  – Michelle Ryerson – Associate Administrator
Our Aim Statement

To ensure that all patients’ radiation exposure is below 2Gy for each fluoroscopy procedure by 3 months.
Background

• **Radiation**: ionizing energy that 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 (compared to radiography), high exposures to patients can result from the large series of images that are encountered in fluoroscopic procedures.
Radiation

- **Absorbed Dose**: 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. The special name for this unit is the 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**: A quantity used for radiation protection purposes that 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.

Quality Improvement Guidelines for Recording Patient Radiation Dose in the Medical Record, JVIR, Volume 20, Issue 7, Supplement, Pages S200-S207 (July 2009)
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.
Radiation Side effects

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

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

Dose

stochastic effects
- Cancer
- Genetic
- Prob \( \propto \) dose

Deterministic effects
- Cataract
- infertility
- erythema
- epilation

Effect
The characteristic changes and injury that we get is a posterior subcapsular cataract

- Ziv Haskal MD

The median age of the radiologists was 45 years.

In practice for a median of 11 years, (range 1 to 39)

Initial findings showed that 22 (37.2%) of the 59 volunteers had small dot-like opacities in the PSC region of the lens, radiation damage.

Standard slit lamp exam, not imaging. In the hands of an ophthalmologist aware of the problems should be able to detect early PSC changes, but will not provide good documentation. Scheimpflug images in combination with retroillumination would be first choice for imaging and documentation.

For the most part, while the changes were detectable in the images, the radiologists didn’t notice any change in vision. Dr. Haskal said. With age-related cataracts, visual acuity drops while posterior subcapsular cataracts can lead to decreased contract sensitivity.

The lens of the eye consists of some of the most radiation sensitive tissue of the body. Interestingly, other studies have shown that if the nucleus is removed and radiated no cataract forms. The damage from ionizing radiation occurs in the germinative zone at the edge of the lens, Dr. Haskal explained.

Dr. Junk pointed out that the daily close proximity to radiation sources of interventional radiologists in the study differs from that of other types of radiologists, such as those who do diagnostics only.

The findings are early and there are still a lot of unanswered questions. There are still hundreds of images to sort through to look for changes, and the numbers of PSC found may change, said Dr. Haskal. He also pointed out that there were some confounders in the study, such as the fact that seven of the subjects had received steroids at some point which can also lead to PSC cataracts.

Just what the rates are of cataracts among interventional radiologists overall, or what the actual risk to this physician group is not yet known. There are also questions about what the cataract risks for other radiologists and technicians might be. The study’s compelling findings highlight the need for further studies involving larger groups of radiologists, Dr. Haskal said.

The researchers are currently collecting additional information from the study’s participants. They want to find out details such as where each radiologist stands when performing interventional procedures. If a radiologist tends to stand to one side, then there could be a slidedness to the eye damage, such as in the left eye only, he said.

The findings of this study support the idea that interventional radiologists should have an annual eye exam, Dr. Junk advised.

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Radiation Measurement

• **Deterministic Effects** - **Peak Skin Dose (PSD):** The highest dose at any portion of a patient's skin during a procedure.

• **Stochastic (Random) 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.
Factors that Increase Entrance Dose

- Long duration of fluoroscopy
- Use of high-intensity mode
- Maintenance of a single angle of view
- Patient obesity
- Cranio-caudal angulation of the X-ray beam
- High image magnification
- No dose monitoring
- X-ray machine defects
Maximum local skin dose (MSD or PSD) assessment

- On-line methods
- Off-line methods
MSD: on-line methods

- Zinc-Cadmium based sensor, Linked to a calibrated digital counter, Position sensor on patient, in the X ray field, Real-time readout in mGy
- Point detectors (ion chamber, diode and Mosfet detectors)
- Dose to Interventional Radiology 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, …)
MSD: off-line methods

– Area detectors: TLD grid

• Dose distribution is obtained with interpolation of point dose data
## Threshold Skin Entrance Doses for Different Skin Injuries

<table>
<thead>
<tr>
<th>Effect</th>
<th>Single-Dose Threshold (Gy)</th>
<th>Onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Early transient erythema</td>
<td>2</td>
<td>Hours</td>
</tr>
<tr>
<td>Main erythema</td>
<td>6</td>
<td>~10 d</td>
</tr>
<tr>
<td>Temporary hair loss</td>
<td>3</td>
<td>~3 wk</td>
</tr>
<tr>
<td>Permanent hair loss</td>
<td>7</td>
<td>~3 wk</td>
</tr>
<tr>
<td>Dry desquamation</td>
<td>14</td>
<td>~4 wk</td>
</tr>
<tr>
<td>Moist desquamation</td>
<td>18</td>
<td>~4 wk</td>
</tr>
<tr>
<td>Secondary ulceration</td>
<td>24</td>
<td>&gt;6 wk</td>
</tr>
<tr>
<td>Late erythema</td>
<td>15</td>
<td>~6–10 wk</td>
</tr>
<tr>
<td>Ischemic dermal necrosis</td>
<td>18</td>
<td>&gt;10 wk</td>
</tr>
<tr>
<td>Dermal atrophy (1st phase)</td>
<td>10</td>
<td>&gt;14 wk</td>
</tr>
<tr>
<td>Dermal atrophy (2nd phase)</td>
<td>10</td>
<td>&gt;1 yr</td>
</tr>
<tr>
<td>Induration (invasive fibrosis)</td>
<td>10</td>
<td>&gt;1 yr</td>
</tr>
<tr>
<td>Telangiectasia</td>
<td>10</td>
<td>&gt;1 yr</td>
</tr>
<tr>
<td>Late dermal necrosis</td>
<td>&gt;12?</td>
<td>&gt;1 yr</td>
</tr>
<tr>
<td>Skin cancer</td>
<td>not known</td>
<td>&gt;5 yr</td>
</tr>
</tbody>
</table>

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

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

6-8 weeks after multiple coronary angiographic and angioplasty procedures  

Injury approximately 16-21 weeks after procedure  

18-21 months after procedure. Tissue necrosis is evident  

Close up of last photograph in previous slide

Area of back after skin grafts

Fishbone Diagram

Patient
- Patient size
- Patient age
- Total radiation dose within 30 days

Procedure
- Type of procedure
- Pre-existing anatomy which may increase complexity
- Shielding technique

Physician
- Technique
- x-ray tube rotation
- use of last image hold
- Collimation
- number of angiographic runs

Physicist
- Lack of interaction with technologists, nurses, and physicians

Factors which affect the fluoroscopic dose and time for patients
- Lack of reporting of > 60 mins cases
Pre-intervention Flow Chart

1. Request made for procedure
2. Request reviewed through pre-evaluation process
3. Appt made for patient by IR facilitator
4. Procedure is started
5. Fluoro time reaches 60 min, Physician is notified
6. If procedure has > 60 minutes fluoroscopic time, Dr. Hatab is notified of case by IR
7. Dr. Hatab calculates the peak skin dose
8. If peak skin dose > 2 Gy, the patient and the referring physician are informed
9. Proper follow-up is initiated
Intervention

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

Request made for procedure

Request reviewed through pre-evaluation process

Appointment is made for patient by IR facilitator

Procedure is initiated

Fluoro time is monitored by technologist during procedure

Fluoro time reaches 50 minutes, Physician is notified

Physician determines if case can be completed in 10 minutes or less of additional fluoro time

No

Do the benefits of continuing outweigh the risks?

No

Case is stopped

Yes

Procedure continues

Is fluoro time ≥ 60 minutes?

No

Dr Hatab is notified of procedure

Dr Hatab calculates radiation exposure

Is radiation exposure ≥ 2 Gy?

No

Pt is seen in I.R. clinic for follow-up

Patient’s primary physician is notified instructed on continued follow-up care for possible skin injury

Yes
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.
Fluoro time

Gys

Indicates time of intervention
Return on Investment

Implementation of this new process:

- Did not increase the cost to the health institute or to the patient
- Was easily implemented into the current department processes
- May potentially prevent any additional health care cost the patient may incur related to radiation exposure injuries.
Expansion of Our Implementation

Our hope is to develop a template that can be implemented in other areas of health care where live fluoroscopy is used, such as:

- cardiology
- rehab medicine
- vascular and thoracic surgery
Conclusion

Benefits:

• To the patient
• To the team
• To the hospital
Thank you!