RADIOLOGY SAFETY
IN THE
MEDICAL IMAGING DEPARTMENT

For the Grand Canyon State Chapter of The American Radiological Nurses Association
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Ionizing Radiation

Nuclear Radiation

| Alpha     | Heavy ions |
| Beta      | Electron beam |
| Gamma     | X-ray |
| Neutron   | |

Atomic Radiation

| Alpha     | Heavy ions |
| Beta      | Electron beam |
| Gamma     | X-ray |
| Neutron   | |

Non-ionizing Radiation

* Ultraviolet
* Visible light
* Infrared
* Microwave
* Radio wave
* Laser
* Ultrasound
* Sound wave
Radiation Units

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Unit</th>
<th>SI Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure</td>
<td>R</td>
<td>C/kg</td>
</tr>
<tr>
<td>Dose</td>
<td>rad</td>
<td>Gy</td>
</tr>
<tr>
<td>Dose Equiv</td>
<td>rem</td>
<td>Sv</td>
</tr>
<tr>
<td>Activity</td>
<td>Ci</td>
<td>Bq</td>
</tr>
</tbody>
</table>

Depending on the kind of radiation, the total dose, the rate of dose, etc., the health effects vary widely, but in general:

- Biochemical effects are seen in SECONDS
- Cell division effects are seen in HOURS
- Gastrointestinal and Central Nervous System effects may be seen in a matter of DAYS
- CANCER may be seen in YEARS
- Genetic Effects may be seen in OFFSPRING

Health Effects of Radiation

Ionizing Radiation can directly and indirectly damage DNA

- Radiation can damage DNA
- Double Helix

Dose Response Model

- Known Effects
  - Atomic Bomb Survivors
  - Uranium Miners
  - Radium Dial Painters
  - Medical Patients

Health effects are seen only when dose exceeds 10 rem and at a high dose rate

- Occupational radiation doses are monitored and limited to 5 rem
- For 95% of the Radiation Users at BGMC, doses are too low to measure
Background Radiation Dose

- **Radon** 55%
- **Internal** 11%
- **Medical** 11%
- **Terrestrial** 8%
- **Cosmic** 8%
- **Other** <1%
- **Products** 3%

Average Background Dose in U.S. is ~360 mrem.

In Colorado it is ~450 mrem.

ALARA

- **Philosophy**
  - As Low As Reasonably Achievable

Radiation doses are kept as low as possible. Stems from Linear-No-Threshold dose model. ALARA program required by Federal and State regulations.

We are required to evaluate each of the following:

1. Deep Dose Equivalent (at a tissue depth of 1 cm)
2. Whole Body Shallow Dose Equivalent (<0.7mm)
3. Eye Dose Equivalent to the Lens of the Eye (3mm)
4. Shallow Dose Equivalent to Maximally Exposed Extremity

Radiation Sources at BGSMC

- Radiation generators (x-rays)
  - Radiology
  - Cardiac cath labs
  - Radiation Oncology
  - Mobil units
- Radioactive materials
  - Nuclear Medicine/PET
  - Radiation Oncology
  - Cath Labs/Labs
  - Radioactive patients
We are also required to evaluate each of the following:

5. Committed Effective Dose Equivalent (<ALI)
6. Committed Dose Equivalent to the Maximally Exposed Organ
7. Total Organ Dose Equivalent
8. Total Effective Dose Equivalent

Annual Limit on Intake (ALI)
The ALI is the annual intake of a given radionuclide by "Reference Man" which would result in either a committed effective dose equivalent of 5 rems or a committed dose equivalent of 50 rems to an organ or tissue.

Total Effective Dose Equivalent

The Total Effective Dose Equivalent (TEDE) is the sum of the Deep Dose Equivalent (DDE) and the Committed Effective Dose Equivalent (CEDE).

\[ \text{TEDE} = \text{DDE} + \text{CEDE} \]

Regulatory Requirements for External Radiation Monitoring

<table>
<thead>
<tr>
<th></th>
<th>DDE</th>
<th>CEDE</th>
<th>SDE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adults</td>
<td>5000</td>
<td>15,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Minors</td>
<td>500</td>
<td>1,500</td>
<td>5,000</td>
</tr>
</tbody>
</table>

All readings in millirem.
**Dose Limits**

- TEDE 0.05 Sv/y  5 rems/y
- Eye dose 0.15 Sv/y  15 rems/y
- Skin 0.5 Sv/y  50 rems/y
- Others 0.5 Sv/y  50 rems/y

**Occupational Dose Limit**

* Excludes background radiation
* Excludes medical radiation
* TEDE = DDE + CEDE = EXT + INT
* Has been reduced over the years
* Dose limit for general public is 2% (1mSv/yr)
* Dose to minor is 10%(5mSv/yr)

**Minimum Personal Protective Equipment for X-ray**

Depending on your work, PPE may include:

- Lead Goggles
- Thyroid Collar
- Lead Apron
- Lead Gloves

No one is permitted to be exposed to the primary beam

**Radiation Badge Report**
A WB badge consists of an integrated, self-contained packet that comes preloaded, incorporating an Al₂O₃ strip sandwiched within a three-element filter pack that is heat sealed within a laminated, light-tight paper wrapper.
**WB Badges may be damaged if...**

They are subjected to physical stress (excessive heat, humidity, mechanical pressure, etc.)

**WB Badges have been damaged by...**

- Being washed
- Being left on the car dashboard in July
- Being stepped on
- Removing the protective covering with a paper clip

**Badge Storage**

Your badge should be stored in a cool, dry place away from all sources of radiation and chemically active gases or vapors.

**Worker's Right**

1. Consultation on radiation safety.
2. Information on radiation exposure.
3. Evaluation on radiation procedure.
4. Safe working facility.
5. Adequate equipments.
6. Proper training and in-service.
Worker's Responsibility
1. Keep exposure ALARA.
2. Acquaint with regulations.
3. Wear radiation monitors.
4. Observe good procedures.
5. Notify RSO about incidents.
6. Maintain proper records.

Regulatory Agencies
- Nuclear Regulatory Commission
- Food and Drug Administration
- Arizona Radiation Regulatory Agency
  - ARRA radioactive material license 7-478
  - X-ray machine registration 07-H-481

Arizona is an AGREEMENT STATE.
Arizona Radiation Regulatory Agency (ARRA) regulates the use of radiation.

State Regulations
- Arizona Revised Statutes
  - Title 30 Power
  - Title 32 Professions and Occupations
- Arizona Administrative Code - Title 12, Chapter 1
  - Article 3: Radioactive Materials License
  - Article 4: Standards for Radiation Protection
  - Article 6: Medical Use of X-rays
  - Article 7: Medical Use of Radioactive Materials
  - Article 9: Particle Accelerators
Security

As a result of September 11, 2001, the Office of Homeland Security requires increased vigilance and that we:

Secure All Radioactive Materials

Weapons of Mass Destruction

- Chemical weapons
- Biological weapons
- Nuclear terrorist
  - Nuclear devices
  - Special radioactive material
  - Attack of nuclear facility
  - Dirty Bomb

PREGNANCY AND MEDICAL RADIATION

- Rapidly dividing and non-specialized cells are more sensitive to radiation
- Birth defects have been observed
- Dose limit to embryo/fetus is 500 mrem for the gestation period

Radiation Effects for Embryo
Declaration of Pregnancy for Occupational Mothers
Protecting the Embryo/Fetus

- The only way to protect the embryo/fetus from excess radiation is to protect the mother
  - “Belly” badge for the baby is issued
  - Bioassay for radioactive material intake is initiated and repeated monthly
- Dose to baby is measured/estimated and reported
- To protect her baby, a mother must voluntarily, in writing, declare herself pregnant
  - Present to the Supervisor and to the Radiation Safety Officer
- Additional information is available through the Radiation Safety Officer
- Confidential discussions with RSO about radiation risks to embryo/fetus
  - Even if just planning to get pregnant
  - Arrangements may be made to discuss with female radiation health professional

Introduction

- Thousands of pregnant women are exposed to ionizing radiation each year
- Lack of knowledge is responsible for great anxiety and probably unnecessary termination of pregnancies
- For most patients, radiation exposure is medically appropriate and the radiation risk to the fetus is minimal

Fetal radiation risk

- There are radiation-related risks throughout pregnancy that are related to the stage of pregnancy and absorbed dose
- Radiation risks are most significant during organogenesis and in the early fetal period, somewhat less in the 2nd trimester, and least in the 3rd trimester

Radiation-induced malformations

- Malformations have a threshold of 10,000–20,000 mrem or higher and are typically associated with central nervous system problems
- Fetal doses of 10,000 mrem are not reached even with 3 pelvic CT scans or 20 conventional diagnostic x-ray examinations
- These levels can be reached with fluoroscopically guided interventional procedures of the pelvis and with radiotherapy
**Central nervous system effects**

- During 8-25 weeks post-conception the CNS is particularly sensitive to radiation.
- Fetal doses in excess of 10,000 mrem can result in some reduction of IQ (intelligence quotient).
- Fetal doses in the range of 100,000 mrem can result in severe mental retardation and microcephaly, particularly during 8-15 weeks and to a lesser extent at 16-25 weeks.

**Leukaemia and cancer...**

- Radiation has been shown to increase the risk for leukaemia and many types of cancer in adults and children.
- Throughout most of pregnancy, the embryo/fetus is assumed to be at about the same risk for carcinogenic effects as children.

**Leukaemia and cancer (cont’d)**

- The relative risk may be as high as 1.4 (40% increase over normal incidence) due to a fetal dose of 1000 mrem.
- For an individual exposed in utero to 1000 mrem, the absolute risk of cancer at ages 0-15 is about 1 excess cancer death per 1,700.

**Probability of bearing healthy children as a function of radiation dose**

<table>
<thead>
<tr>
<th>Dose to conceptus (mrem) above natural background</th>
<th>Probability of no malformation</th>
<th>Probability of no cancer (0-19 years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>97</td>
<td>99.7</td>
</tr>
<tr>
<td>100</td>
<td>97</td>
<td>99.7</td>
</tr>
<tr>
<td>500</td>
<td>97</td>
<td>99.7</td>
</tr>
<tr>
<td>1000</td>
<td>97</td>
<td>99.6</td>
</tr>
<tr>
<td>5000</td>
<td>97</td>
<td>99.4</td>
</tr>
<tr>
<td>10,000</td>
<td>97</td>
<td>99.1</td>
</tr>
<tr>
<td>&gt;10,000</td>
<td>Possible</td>
<td>Higher</td>
</tr>
</tbody>
</table>
Pre-conception irradiation

- Pre-conception irradiation of either parent’s gonads has not been shown to result in increased risk of cancer or malformations in children.
- This statement is from comprehensive studies of atomic bomb survivors as well as studies of patients who had been treated with radiotherapy when they were children.

Informed consent and understanding

- The pregnant patient or worker has a right to know the magnitude and type of potential radiation effects that might result from in-utero exposure.
- Communication should be related to the level of risk. Communication that risk is negligible is adequate for very low dose procedures (<1 mGy to the fetus).
- If fetal doses are above 100 mrem, a more detailed explanation should be given.

Exposure of pregnant patients

- In some circumstances, the exposure is inappropriate and the unborn child may be at increased risk of harm to health.
- Prenatal doses from most properly performed diagnostic procedures present no measurably increased risk of prenatal death, malformation, or mental impairment.
- Higher doses such as those from therapeutic procedures can result in significant fetal harm.

Medical radiation procedures

- All medical practices (occupational and patient-related) should be justified (more benefit than risk).
- Medical exposures should be justified for each patient before they are performed.
- After it is decided to do a medical radiation procedure, the fetal radiation dose should be reduced while still obtaining the required diagnostic information.
In females of child-bearing age, an attempt should be made to determine who is, or could be, pregnant, prior to radiation exposure.

A missed period in a regularly menstruating woman should be considered due to pregnancy, until proven otherwise.

Notices regarding pregnancy should be posted in patient waiting areas, such as:

- If it is possible that you might be pregnant, notify the physician or other staff before your x-ray examination, treatment, or before being injected with a radioactive material.

### Approximate fetal doses from conventional x-ray examinations

**Data from the UK, 1998**

<table>
<thead>
<tr>
<th>Examination</th>
<th>Dose</th>
<th>Mean (mrem)</th>
<th>Maximum (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abdomen</td>
<td>140</td>
<td>420</td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>Intravenous urogram; lumbar spine</td>
<td>170</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>Pelvis</td>
<td>110</td>
<td>400</td>
<td></td>
</tr>
<tr>
<td>Skull; thoracic spine</td>
<td>&lt;1</td>
<td>&lt;1</td>
<td></td>
</tr>
</tbody>
</table>

### Approximate fetal doses from fluoroscopic and computed tomography procedures

**Data from the UK, 1998**

<table>
<thead>
<tr>
<th>Examination</th>
<th>Dose</th>
<th>Mean (mrem)</th>
<th>Maximum (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barium meal (UGI)</td>
<td>110</td>
<td>580</td>
<td></td>
</tr>
<tr>
<td>Barium enema</td>
<td>680</td>
<td>2400</td>
<td></td>
</tr>
<tr>
<td>Head CT</td>
<td>&lt;0.5</td>
<td>&lt;0.5</td>
<td></td>
</tr>
<tr>
<td>Chest CT</td>
<td>6</td>
<td>100</td>
<td></td>
</tr>
<tr>
<td>Abdomen CT</td>
<td>800</td>
<td>4900</td>
<td></td>
</tr>
<tr>
<td>Pelvis CT</td>
<td>2500</td>
<td>8000</td>
<td></td>
</tr>
</tbody>
</table>
Higher dose procedures

- Radiation therapy and interventional fluoroscopically-guided procedures may give fetal doses in the range of 1000-10,000 mrem or more depending on the specifics of the procedure.
- When such higher dose medical procedures have been performed on pregnant patients, fetal dose and potential fetal risk should be estimated by a knowledgeable person.

Termination of pregnancy...

- High fetal doses (10,000-100,000 mrem) during late pregnancy are not likely to result in malformations or birth defects since all the organs have been formed.
- A fetal dose of 10,000 mrem has a small individual risk of radiation-induced cancer. There is over a 99% chance that the exposed fetus will NOT develop childhood cancer or leukaemia.

Radiation exposure of pregnant workers

- Pregnant medical radiation workers may work in a radiation environment as long as there is reasonable assurance that the fetal dose can be kept below 100 mrem during the pregnancy.
- 100 mrem is approximately the dose that all persons receive annually from penetrating natural background radiation.

Termination of pregnancy (cont'd)

- Termination of pregnancy at fetal doses of less than 10,000 mrem is NOT justified based upon radiation risk.
- At fetal doses in excess of 50,000 mrem, there can be significant fetal damage, the magnitude and type of which is a function of dose and stage of pregnancy.
- At fetal doses between 10,000 and 50,000 mrem, decisions should be based upon individual circumstances.
Risks in a pregnant population not exposed to radiation

- Spontaneous abortion (miscarriage) > 15%
- Incidence of genetic abnormalities 4-10%
- Intrauterine growth retardation 4%
- Incidence of major malformation 2-4%

Radiation in Radiology

- X-ray generators
- Computed Tomography
- Fluoroscopy

X-ray Tube

- Fancy lightbulb – high voltage vacuum tube
- Cathode e- source and Anode target
- Electrons accelerated (high voltage) across vacuum
- Suddenly decelerated (smacked) into high Z target
- Conservation of Energy: Electron kinetic energy \( \frac{1}{2}mv^2 \) converted into heat and E-M Radiation
  - (1% efficient)

Rotating anode tubes – necessary for heat dissipation (poor X-ray production efficiency)
Medical X-Ray

- X-Rays occur naturally, however …
- All medical X-ray generated by machine …
  - With X-ray Tube connected to High Voltage Generator
  - Conversion of Electrical Energy to Electromagnetic Radiation

- No radiation emitted when “off”
- Cannot induce radioactivity!

Trends in X-ray Doses

- For any given exam, technology has decreased patient dose.
- Old exams used “soft” beam with many low energy components.
- New exams use much higher energy and better detectors.

MANAGING PATIENT DOSE IN RADIOLOGY (CT)

CT continues to evolve rapidly despite many advances in other imaging modalities
- It is one of the most important radiological examinations worldwide
- The frequency of CT examinations is increasing rapidly from 2% of all radiological examinations in some countries a decade ago to 10-15% now
- Patient doses in CT have not decreased in contrast to radiography where nearly 30% reduction has been documented in last decade
20 years ago, a standard CT of the thorax took several minutes while today similar information can be accumulated in a single breath hold making it attractive, patient & user friendly.

Advances in CT technology have made possible CT fluoroscopy and interventional procedures, in some cases replacing ultrasound guided interventions.

Recently CT screening is picking up.

Unlike radiography where over-exposure results in blackening of film, better image quality is obtained with higher exposures in CT.

There is a tendency to increase the volume covered in a particular examination.

Modern helical CT involves volume scanning with no inter-slice gap and with possibility of overlapping scans.

Repeat CT examinations.

Same exposure factors used for children as for adult.

Same exposure factors for pelvic (high contrast region) as for abdomen (low contrast region).
The effective dose in chest CT is in the order of 8 mSv (around 400 times more than chest radiograph dose) and in some CT examinations like that of pelvic region, it may be around 20 mSv.

The absorbed dose to tissues from CT can often approach or exceed the levels known to increase the probability of cancer as shown in epidemiological studies.

### Organ doses in CT

- Breast dose in thorax CT may be as much as 3000-5000 mrem, even though breasts are not the target of imaging procedure.
- Eye lens dose in brain CT, thyroid in brain or in thorax CT and gonads in pelvic CT receive high doses.

### Effective doses in CT and radiographic examinations

<table>
<thead>
<tr>
<th>CT examination</th>
<th>Effective dose (mrem)</th>
<th>Radiographic examination</th>
<th>Effective dose (mrem)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>200</td>
<td>Skull</td>
<td>7</td>
</tr>
<tr>
<td>Chest</td>
<td>800</td>
<td>Chest PA</td>
<td>2</td>
</tr>
<tr>
<td>Abdomen</td>
<td>1000-2000</td>
<td>Abdomen</td>
<td>100</td>
</tr>
<tr>
<td>Pelvis</td>
<td>1000-2000</td>
<td>Pelvis</td>
<td>70</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ba swallow</td>
<td>150</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Ba enema</td>
<td>700</td>
</tr>
</tbody>
</table>
### Typical doses (mrem) during CT in adults
(Shrimpton et al. 1991)

<table>
<thead>
<tr>
<th>Examination</th>
<th>Eyes</th>
<th>Thyroid</th>
<th>Breast</th>
<th>Uterus</th>
<th>Ovaries</th>
<th>Testes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head</td>
<td>5000</td>
<td>190</td>
<td>3</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Cervical spine</td>
<td>62</td>
<td>4400</td>
<td>9</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Thoracic spine</td>
<td>4</td>
<td>46</td>
<td>2800</td>
<td>2</td>
<td>2</td>
<td>*</td>
</tr>
<tr>
<td>Chest</td>
<td>14</td>
<td>230</td>
<td>2100</td>
<td>6</td>
<td>8</td>
<td>*</td>
</tr>
<tr>
<td>Abdomen</td>
<td>*</td>
<td>5</td>
<td>72</td>
<td>800</td>
<td>800</td>
<td>70</td>
</tr>
<tr>
<td>L. spine</td>
<td>*</td>
<td>1</td>
<td>13</td>
<td>240</td>
<td>270</td>
<td>6</td>
</tr>
<tr>
<td>Pelvis</td>
<td>*</td>
<td>*</td>
<td>3</td>
<td>2600</td>
<td>2300</td>
<td>170</td>
</tr>
</tbody>
</table>

The symbol * indicates that dose is < 0.5 mrem

### Does spiral CT give more or less radiation dose?

- It depends upon the choice of factors
- Even though it is possible to perform a spiral CT with lower radiation dose than slice-by-slice CT, in practice the patient gets higher dose due to the factors chosen (scan volume, mAs, pitch, slice width)

### Does multi-slice CT impart more or less radiation dose?

- An increase by 10-30% may occur with multi-slice detector array

### Some observations

- Most doctors including many radiologists have a feeling that modern CT scanners which are very fast give lesser radiation dose
- Unfortunately ‘time’ and ‘radiation dose’ are not proportional in such a situation
- Over the years the x-ray tubes are becoming more and more powerful such that they can give high bursts of x-rays which can give satisfactory image in shorter exposure time
WHAT CAN BE DONE TO MANAGE PATIENT DOSE IN CT?

Limit the scanned volume
Reduce mAs values
Use automatic exposure control by adapting the scanning parameters to the patient cross section. 10-50% reduction in dose documented, without any loss of image quality

What can operators do (cont’d)

Use of spiral CT with pitch factor>1 and calculation of overlapping images instead of acquiring overlapping single scans
Shielding of superficial organs such as thyroid, breast, eye lens and gonads particularly in children and young adults. This results in 30-60% dose reduction to the organ

Separate factors for children. Can reduce dose by a factor of 5 or more
Use of partial rotation e.g. 270 degree in Head CT
Adequate selection of image reconstruction parameters
Use of z-filtering with multi-slice CT systems
Record of dose, exposure factors
Actions for physician & radiologist...

- **Justification**: Ensure that patients are not irradiated unjustifiably.
- Request for CT examination should be generated only by properly qualified medical or dental practitioners depending upon national educational and qualification system. The physician is responsible for weighing the benefits against risks.
- Clinical guidelines advising which examinations are appropriate and acceptable should be available to clinicians and radiologists.

Actions for physician & radiologist (cont’d)

- CT examination should **not be repeated** without clinical justification and should be limited to the area of interest.
- Clinician has the **responsibility** to communicate to the radiologist about previous CT examination of the patient.
- CT examination for **research** purpose that do not have clinical justification (immediate benefit to the person undergoing the examination) should be subject to critical evaluation by an ethics committee.

Actions for physician & radiologist (cont’d)

- Consider whether the required information be obtained by MRI, ultrasonography.
- Consider value of contrast medium enhancement prior to commencing examination.
- CT scanning in pregnancy may not be contraindicated, particularly in emergency situations, although examinations of the abdomen or pelvis should be carefully justified.

Actions for physician & radiologist (cont’d)

- CT examination of chest in young girls and young females needs to be justified in view of high breast dose.
- Once the examination has been justified, radiologist has the primary responsibility for ensuring that the examination is carried out with good technique.
- Information abstracted from ICRP Publications 84, 86 and 87
- Available at www.icrp.org

**Fluoroscopy is the greatest source of staff radiation exposure and a significant risk to patients**

**Web sites for additional information on radiation sources and effects**
- European Commission (radiological protection pages): europa.eu.int/comm/environment/radprot
- International Atomic Energy Agency: www.iaea.org
- International Commission on Radiological Protection: www.icrp.org
- World Health Organization: www.who.int

**FDA Fluoroscopy Advisory**
Typical procedures that could lead to injury
- RF Cardiac Catheter Ablation
- Vascular Embolization
- Transjugular Interhepatic Portosystemic Shunt
- Percutaneous Endovascular Reconstruction
- Any procedure with beam stationary for long periods or extended radiographic sequences
- Any procedure where the patient is very close to the x-ray tube port

1994 FDA Advisory
**FDA Fluoroscopy Advisory**

**Institutional Response**
- Establish standard operating procedures
- Know radiation dose rates
- Educate users
- Modify procedure protocols, as appropriate, to limit cumulative absorbed dose
- Enlist qualified medical physicist to assist in implementing response

**What causes high exposures?**
- More procedures
- Poor equipment
- Poor technique

**How do we reduce fluoro exposure?**
- New equipment with new federally mandated requirements
- Optimizing setup of fluoro
- Using the least amount of imaging sufficient for your procedures

**New JCAHO guidelines**

Reviewable sentinel events expanded to include radiation overdose
The list of sentinel events subject to review by the Joint Commission has been expanded to include radiation overdose involving prolonged fluoroscopy with cumulative dose more than 1500 rads to a single field or any delivery of radiotherapy to the wrong body region or more than 25 percent above the planned radiotherapy dose.
The FDA Center for Devices and Radiological Health [1] has implemented nine changes to the U.S. Performance Standard for Diagnostic X-Ray Equipment that will reduce unnecessary radiation emitted during fluoroscopy. Principal radiation risks to patients are a long-term possibility for cancer induction and a short-term potential for skin burns. We estimate benefits of these amendments in terms of years of life that would be spared cancer mortality attributable to excess radiation, numbers of radiation burns that would be avoided, and their respective pecuniary savings to society.

**New Requirements [2]**

would require that new fluoroscopy equipment

- Display the rate, time, and cumulative total of radiation emission
- Filter out more of the lower energy x-rays to reduce dose to patient skin
- Collimate the x-ray field more “tightly” so that it’s used more efficiently
- 5 minute warning is removed

**Display Amendment**

- Rate, time, total amounts of radiation exposure displayed to radiologist
- Radiologist could use exposure data to optimize exam techniques
- Facility could compare, control emissions according to exam norms

**Expected Impact:** could reduce overall patient dose ~ 16%

**Filtration Amendment**

- More filtration selectively absorbs low-energy x-rays
- Spares the patient skin dose and potential radiation burn

**Expected Impact:** could reduce overall patient dose - 6%
Collimation Amendment

- "Tighter" collimation: \( \text{image area} \geq 80\% \times \text{x-ray field area} \)
- Reduces radiation not used for imaging

• Expected Impact:
  - Could reduce overall patient dose ~ 1% (UGI) + 3% (cardio)

The C-arm fluoroscopic configuration

A

- 1.0 Dose Unit
- TIPS example: 4 Gy
- Temporary epilation
- 30 cm 80 cm

B

- 1.5 Dose Units
- TIPS example: 6 Gy
- Delayed erythema
- 45 cm 65 cm

C

- 2.5 Dose Units
- TIPS example: 10 Gy
- Desquamation
- 60 cm 50 cm

D

- 5.2 Dose Units
- TIPS example: 21 Gy
- Dermal necrosis
- 75 cm 35 cm
101
40 year old male, 8 weeks post cardiac angiography (2) and angioplasty

102
21 weeks post

103
21 months post procedure

104
Documented Skin Injury from Fluoroscopy, > 200 rad

105
Before and After Skin Graft
**Radiation Protection Basics**

- Stay out of the Primary Beam
  - Don’t hold patients
- Scattered radiation from the patient is the primary source of staff exposure

**Controlling dose to patients and staff**

- Keep beam-on time to a minimum (use pedal sparingly and only when actually looking at screen)
- Use pulse mode when possible
  - Gives optimally brief exposure and freezes image
  - Number of pulses per sec should be set to minimum acceptable for real time imaging
- Remember dose rates will be greater and dose accumulates faster in larger patients
- Keep tube current as low as possible and tube potential (kVp) as high as possible (usually set automatically)
- Keep x-ray tube at maximum and the image intensifier at minimum distance from patient

**Controlling dose to patients and staff (cont’d)**

- Always collimate closely to the area of interest (use smallest field size)
- Prolonged procedures: reduce dose to the irradiated skin by changing beam angulation
- Minimize: fluoro time, cine (high dose rate) time & number of acquisitions
- Do not use geometric magnification, use digital magnification whenever needed.
- Remove grid for small patients or when image intensifier cannot be placed close to patient
Controlling dose to staff

- Wear protective apron, thyroid shield & glasses, use shielding, monitor doses – whole body and hand
- Use correct positioning to machine to minimize dose
- If beam is horizontal (or near to), operator should stand on image intensifier side, when possible
- If beam is vertical (or near to), keep the tube under the patient

REMEMBER:
- Reducing dose to the patient will reduce dose to the staff!

Policy for excessive fluoro time

- Review chart for prior fluoroscopy
- Notify physician after 30 min and every 5 min after
- At 60 min fluoro time, document in chart reason and notify patient. Fill out new chart documentation
- At 90 min do all above plus notify Risk Management and RSO for dose evaluation

Credentialing / privileges for fluoroscopy
- Current staff will be grandfathered with annual refresher training
- New staff must receive training
- Non routine users may need proctoring
Suggested Reading

Cutaneous Radiation Injury: Fact Sheet for Physicians
http://www.bt.cdc.gov/radiation/criphysicianfactsheet.asp

References


Thank you