Hello and welcome to Fluoroscopy Safety Training presented by LANDAUER Medical Physics. This training is for those who work directly with or around radiation generating devices capable of fluoroscopic imaging. This course is intended to meet The Joint Commission requirements for individuals who operate Fluoroscopic x-ray equipment.
Section 1
Principles of Radiation Safety
Fluoroscopy is the use of a continuous X-ray beam to generate medical images in real time.

Fluoroscopy is the use of a continuous x-ray beam to generate medical images in real time.
Principles of Radiation Safety

• ALARA – As Low As Reasonably Achievable – A concept of Radiation Safety that employs the three basic principles of Time, Distance, and Shielding to reduce radiation exposure

• We want to maintain radiation dose as low as diagnostically acceptable, we also want the image quality of our exams to be acceptable enough not to lose the ability to make a diagnosis. Since radiation dose is directly tied to signal to noise ratio, the image with as low as diagnostically acceptable image quality will be the lowest patient dose as well.

• Even though it is easy to reduce radiation exposure, it takes a team to get the lowest exposure while also maintaining the optimal image quality

ALARA – As low as reasonably achievable – is the concept of Radiation Safety that employs the three basic principles of time, distance and shielding to reduce radiation exposure

We want to maintain radiation dose as low as diagnostically acceptable, we also want the image quality of our exams to be acceptable enough not to lose the ability to make a diagnosis. Since radiation dose is directly tied to signal to noise ratio, the image with as low as diagnostically acceptable image quality will be the lowest patient dose as well.

Even though it is easy to reduce radiation exposure, it takes a team to get the lowest exposure while also maintaining the optimal image quality
Principles of Radiation Safety

Time  Distance  Shielding

• Time – Reduce the amount of time that the X-ray tube is energized

• Distance – Increase the amount of distance between yourself and the X-ray source during exposure

• Shielding – Increase the amount of shielding to reduce dose. Use proper personnel protective equipment when working around radiation

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There are 3 ways to reduce your radiation exposure

Time - You can reduce the amount of time that the X-ray tube is energized

Distance – Increase the amount of distance between yourself and the X-ray source during exposure

Shielding – Increase the amount of shielding to reduce dose. Use proper personnel protective equipment when working around radiation
Principles of Radiation Safety

Summary of Radiation Protection Concepts in the Fluoroscopy Suite

- Maximize Patient Distance to X-ray source
- Minimize use of Magnification
- Minimize Fluoro on-time
- Reduce number of frames per second
- Use the last image hold feature
- Change camera angle to reduce peak skin dose, also called Dose Spreading
- Establish Substantial Radiation Dose Levels (SRDL)
- Communicate SRDL triggers to the team when they are first exceeded and continue to communicate as they increase through the trigger levels

Fluoroscopy Safety Training

This is a summary of radiation protection concepts that can be applied to the fluoroscopy suite.

Maximize patient distance to X-ray source
Minimize the use of magnification
Minimize the fluoro on-time
Reduce the number of frames per second
Use of last image hold feature
Change the camera angle to reduce the peak skin dose, also called Dose Spreading
Establish Substantial Radiation Dose Levels (SRDL)
Communicate Substantial Radiation Dose Level triggers to the team when they are first exceeded and continue to communicate as they increase through the trigger levels
Patient Distance to X-ray source and Image Intensifier (Detector) is very important. When the patient is closer to the X-ray source, the patient radiation dose is higher than could be possible. The inverse happens when the patient is moved closer to the Image Intensifier. Image quality is improved while radiation dose is lowered.
### Patient Dose from Various Modalities

<table>
<thead>
<tr>
<th>Modality</th>
<th>Typical Dose Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI</td>
<td>None</td>
</tr>
<tr>
<td>Mammography</td>
<td>0.5 to 3 mGy MGD (50 to 300 mrem)</td>
</tr>
<tr>
<td>Radiographic</td>
<td>0.10 to 4 mGy ESE (10-400 mrem)</td>
</tr>
<tr>
<td>Nuclear Medicine</td>
<td>1 – 50 mGy EDE (100-5000 mrem)</td>
</tr>
<tr>
<td>CT</td>
<td>2 to 80 mGy CTDI (200 to 8000 mrem)</td>
</tr>
<tr>
<td>Fluoroscopic/Interventional</td>
<td>1 to 2000 mGy ESE (100 to 200,000 mrem)</td>
</tr>
</tbody>
</table>

This is a chart of typical patient dose ranges from various modalities.
### Occupational Dose from Various Modalities

<table>
<thead>
<tr>
<th>Modality</th>
<th>Typical Dose Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiographic</td>
<td>0 to 50 mrem per month</td>
</tr>
<tr>
<td>Fluoroscopic/Interventional</td>
<td>25 to 100 mrem per month</td>
</tr>
<tr>
<td>Mammography</td>
<td>0 to 2 mrem per month</td>
</tr>
<tr>
<td>CT</td>
<td>0 to 100 mrem</td>
</tr>
<tr>
<td>Nuclear Medicine-general</td>
<td>10 to 60 mrem per month</td>
</tr>
<tr>
<td>PET</td>
<td>50 to 300 mrem per month</td>
</tr>
<tr>
<td>MRI</td>
<td>None</td>
</tr>
</tbody>
</table>

This is a chart of typical occupational dose ranges from various modalities.
Section 2
Scatter Radiation

Section Two, Scatter Radiation
• Most occupational dose in the fluoroscopy suite comes from scatter radiation
• Secondary radiation is scatter from the primary X-ray beam interacting with everything between the X-ray source and image intensifier
• The patient is the predominant source of this scattered radiation
• In the next two slides, we will illustrate common scatter maps that could be generated by a typical C-arm
This is a representation of the Horizontal Profile of a typical scatter map in Fluoroscopy with X-ray tube in the Posterior-Anterior orientation.

The dose rate is represented by the intensity of the color on the right.
This is a representation of the Vertical Profile of a typical scatter map in Fluoroscopy

The dose rate is represented by the intensity of the color on the right.
Section 3
Patient Dose

Section Three, Patient Dose
Fluoroscopic radiation dose metrics

Fluoroscopic time – Total elapsed time during the procedure when the fluoroscopic X-rays are produced. *Not a good indicator of dose to patient.*

Reference Air Kerma ($K_{a,r}$) – Kinetic energy released per unit mass at the reference point.

Kerma-area product (KAP) / Dose-area product (DAP) (Gy-cm²) – $K_{a,r}$ multiplied by the exposed area. This can be calculated by the system or measured with a large area ion chamber.

Peak skin dose (PSD) – The highest dose received in any one region on the patient’s skin. Includes the backscatter and other tissue factors as well as the beam overlap to estimate the peak dose to any area of skin. This calculation is best performed by a qualified medical physicist. This is the best metric for determining skin effects.
What are the effects of radiation?

Deterministic
- Radiation causes cell-death leading to tissue effects
- Typically have a threshold dose before the effect is observable
- Acute Effects: Erythema (redness), epilation (hair loss)
- Cumulative Effects: Cataracts

Stochastic/Probabilistic
- DNA is permanently altered
- Probability of developing cancer associated with mutation actually causing problems
- Damaged cells may eventually become cancerous, process could take many years
- Current theories state that there is no threshold for carcinogenic effects
- ALARA concept used to minimize the risk
This is a chart showing the relationship between the Peak Skin Dose and possible deterministic effects.

Below 2 Gray, there are no known possible deterministic effects.
Patient Dose

• Before procedure
  • Review past exposures for the last 6-12 months
  • Inform the patient of the risks related to the use of radiation

• During procedure
  • Monitor radiation doses using notification levels
  • Follow best practices to keep doses ALARA

• After procedure
  • Use substantial radiation dose levels (SRDLs) shown on a later slide to evaluate deterministic radiation risks
  • When relevant, use patient self-evaluation to determine proper patient follow-up

Use the checklist at Image Wisely®: https://www.imagewisely.org/Imaging-Modalities/Fluoroscopy/Checklists

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Before the procedure
  Review past exposures for the last 6-12 months
  Inform the patient of the risks related to the use of radiation

During the procedure
  Monitor radiation doses using notification levels
  Follow best practices to keep doses ALARA

After the procedure
  Use substantial radiation dose levels (SRDLs) shown on a later slide to evaluate deterministic radiation risks
  When relevant, use patient self-evaluation to determine proper patient follow-up
Past exposures increase risk factors

- Summation of doses over time overestimates the likelihood of skin reactions as the interval between exposures increases
- Biological repair can take months to complete
- The Joint Commission recommends doses from previous 6-12 months summed
- Other publications recommend period of 6 months
Providing information on risks from radiation

It is best to communicate information about a procedure including the risks from radiation before the day of the procedure.

Inform the patient if the procedure may exceed substantial radiation dose levels (SRDLs).

Inform the patient that these possible skin effects such as redness, blisters, rash, and hair loss are not typical for the average sized patient.

Inform the patient that if substantial radiation dose levels are exceeded, they will be given written instructions.

Reassure the patient that the potentially life saving benefits outweigh the minimal risks introduced from the use of radiation.
Patient Dose

- Notifications
  - Performed during the procedure
  - A procedure does not need to be stopped just because a SRDL has been exceeded
  - All relevant clinical factors should be considered in the continuing benefit-risk evaluation
  - Dose saving techniques should be considered

<table>
<thead>
<tr>
<th>Dose Metric</th>
<th>First Notification</th>
<th>Subsequent Notifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Skin Dose (Gy)</td>
<td>2</td>
<td>0.5</td>
</tr>
<tr>
<td>$K_{eq}$ (Gy)</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>DAP (Gy cm²)</td>
<td>300</td>
<td>100</td>
</tr>
<tr>
<td>Fluoro Time (min)</td>
<td>30</td>
<td>15</td>
</tr>
</tbody>
</table>

Table derived from NCRP Report 168

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Notifications
  - Performed during the procedure
  - A procedure does not need to be stopped just because a SRDL has been exceeded
  - All relevant clinical factors should be considered in the continuing benefit-risk evaluation
  - Dose saving techniques should be considered

The Table below contains notification levels corresponding to the dose metric available
Patient Dose

- **Dose saving techniques**
  - **Patient positioning** – Patient should be as close to the detector and as far from the X-ray source as possible
  - **Dose mode** – Low dose mode uses less dose, but results in more noise. Dose mode can be changed during the procedure as needed.
  - **FOV** – Larger FOVs require less dose to achieve the same brightness as mag modes. Default should be set to largest FOV.
  - **Collimation** – Reduces effective dose to patient and operator. Slight improvement in contrast and decrease in peak skin dose due to less scattered radiation.
  - **Using a low frame rate** – Lower frame rate is associated with lower doses.
  - **Last image hold (LIH)** – Saves last image on the screen. LIH can be approx. $1/10^{th}$ radiographic image dose. Variations include fluoro save, fluoro grab and last fluoro loop replay.
  - **Dose spreading** – When possible, multiple angles can be used to “spread” the dose limiting the skin effects.

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• Substantial Radiation Dose Levels (SRDLs)
  - Trigger patient follow-up
  - Might produce clinically-relevant injury
  - Purpose is to detect skin effects that may require further management
  - If fluoroscopy time exceeds the SRDL, but other metrics do not, patient follow-up may not be necessary
  - Follow-up should be the responsibility of the interventionalist or another appointed health-care provider

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<tr>
<td>$K_{ar}$ (Gy)</td>
<td>5</td>
</tr>
<tr>
<td>DAP (Gy cm$^2$)</td>
<td>500</td>
</tr>
<tr>
<td>Fluoro Time (min)</td>
<td>60</td>
</tr>
</tbody>
</table>

Table derived from NCRP Report 168

Substantial Radiation Dose Levels (SRDLs)
The dose levels below should trigger patient follow-up
Dose at this level could produce clinically-relevant injury
The purpose is to detect skin effects that may require further management
If fluoroscopy time exceeds the SRDL, but other metrics do not, patient follow-up may not be necessary
Follow-up should be the responsibility of the interventionalist or another appointed health-care provider
Patient Dose

- Patient follow-up
  - Inform the patient that their procedure exceeded a substantial radiation dose level.
  - Inform the patient of the skin regions where effects are possible.
  - Have the patient or family member examine skin over the next 4 weeks for possible skin reactions.
  - Notify the patient that these effects may include redness, blisters, rash, or hair loss.
  - Notify the patient that these reactions are rare and are not life threatening, but their effects can be minimized with appropriate care.
  - Provide instructions for who to contact if the patient observes any effects from the radiation.

Fluoroscopy Safety Training

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Provide instructions for who to contact if the patient observes any effects from the radiation.
Pediatric Dose

- How to adjust for a child-size procedure
  - Images should always be of diagnostic quality
  - Make sure proper anatomical protocol is selected
  - Lower kVp can be used in pediatrics to increase contrast
  - Smaller focal spot can be used in pediatrics to increase resolution
  - Remove the grid if possible for patients less than 10 cm
  - Pediatrics may require higher frame rate than adult studies
    - Pediatric cardiac studies typically require 30 pulses per second
    - Pediatric, non-cardiac, interventional studies typically require 15 pulses per second
    - General studies of the GI tract or bladder can use as low as 1-4 pulses per second

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Patient Dose

• The Joint Commission
  • Will require dose to be recorded in a retrievable format (1/1/2019)
  • Will require establishing thresholds for review and patient follow-up (1/1/2019)
• Sentinel Event
  • Dose to a single site exceeds 15 Gray over 6-12 month window
  • Considered a preventable event
  • Root cause analysis is mandatory
  • Voluntary reporting highly encouraged

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Section 4
Image Wisely and Image Gently Campaigns

https://www.imagewisely.org/
https://www.imagegently.org/

Section 4, Image Wisely and Image Gently Campaigns
Image Gently® Campaign

Take the Image Gently® pledge!

Image Gently Mission Statement Update
The mission of the Image Gently Alliance is, through advocacy, to improve safe and effective imaging care of children worldwide.

Campaign Overview
The Image Gently Campaign and the Image Gently Alliance rely on the generous donations of resources from the founding organizations (Society for Pediatric Radiology, American College of Radiology, American Society for Radiologic Technologists, and the American Association of Physicists in Medicine), all Alliance Organizations, supporters, and Cincinnati Children’s Hospital Medical Center. The leadership gratefully acknowledges the time, talent, and expertise from representatives of GE Healthcare, Philips Healthcare, Toshiba America, and Siemens Medical Systems, who are committed to improving healthcare for children through activities related to this campaign.

The Alliance is grateful for the unrestricted educational grant from GE Healthcare made in 2007. The campaign does not accept corporate financial donations at this time.

Take the Pledge

Fluoroscopy Safety Training

View the complete content of Image Gently and take the pledge at the link below
Image Gently® Campaign

- Take the free 2-hour CE Course from the American Society of Radiologic Technologists at the link below to view the complete Image Gently material

http://asrt.mycrowdwisdom.com/diweb/catalog/item/id/170885/q/q=*22image*20gently*22&c=40

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Take the free 2-hour CE Course from the American Society of Radiologic Technologists at the link below to view the complete Image Gently material
Pause and Pulse

- **PAUSE** to properly plan and prepare for the procedure
- Activate dose saving features of equipment
- No image exposures unless necessary
- Download image grab instead
- **PULSE** at lowest possible rate
Image Wisely® Campaign

• Take the Image Wisely® Pledge to:
  • Put my patients’ safety, health, and welfare first
  • Convey the principles of the Image Wisely® Program
  • Communicate optimal patient imaging strategies
  • Routinely review imaging protocols
  • Monitor examination radiation dose indices

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Section 5
Radiation Safety Officer Role

Section 5, Radiation Safety Officer Role
The hospital must designate an individual to serve as the radiation safety officer who is responsible for making certain that radiologic services are provided in accordance with law, regulation, and organizational policy. The individual must have the necessary authority and leadership support to do the following:

- Monitor and verify compliance with established radiation safety practices (including oversight of dosimetry monitoring)
- Provide recommendations for improving radiation safety
- Intervene as needed to stop unsafe practices
- Implement corrective action

Fluoroscopy Safety Training

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Intervene as needed to stop unsafe practices
Implement corrective action
Section 6
Medical Physicist Role

Section 6, Medical Physicist Role
Medical Physicist Role

• Medical Physicists are responsible for the performance evaluation of fluoroscopy imaging equipment **annually** to maintain accreditation standards.

• The evaluation must include an assessment of the following:
  - Beam alignment and collimation
  - Tube potential/kilovolt peak accuracy
  - Beam filtration (half-value layer)
  - High-contrast resolution
  - Low-contrast detectability
  - Maximum exposure rate in all imaging modes
  - Displayed air-kerma rate and cumulative air-kerma accuracy (when applicable)
Medical Physicist Role

- Physicists will test the output at specific locations
  - 0.5 cm above the table for under-table X-ray tubes
  - 30 cm from the II for C-arm designs
  - 30 cm above the table-top for above table X-ray tubes
- An effort to measure output near the skin surface of an average patient
- Output of the X-ray tube is driven by patient size (either by automatic brightness control or measurement of a digital signal). Output is measured using one or more Aluminum or Acrylic blocks to mimic small and average patients
- Maximum output is tested for compliance with FDA rules by the use of a lead plate to block most of the X-ray and drive the output as high as it will go

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Medical Physicist Role

Fluoroscopy Testing Setup

These are common physics testing configurations.
Section 7
Physician Role
• The physician should be able to identify the point at which image quality starts to drop off

• The goal is to slowly reduce the radiation dose until the point where image quality just starts to decline then bring it up to where you know you will always achieve quality images

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Section 8
Technologist Role
• The Technologist should be able to employ the radiation reduction techniques with the advice of the Medical Physicist and the Physician

• The Technologist should be confirming with the physician to ensure that image quality is adequate

The Technologist should be able to employ the radiation reduction techniques with the advice of the Medical Physicist and the Physician

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Section 9
Radiation Protection Devices
Radiation Protection Devices

- External Shields can be ceiling-mounted, under-table, or mobile
- Protective Apron – lead equivalent of 0.5 mm recommended (light weight options are available)
- Thyroid Shields – reduce dose to sensitive organs
- Leaded Glasses – reduce eye dose
- Leaded Gloves – use 0.5 mm lead equivalent to reduce extremity exposure if hands must go in X-ray beam

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This is a list of external shields you could see in the fluoroscopy suite
The use of a real-time dosimetry system can help visualize the radiation exposure to staff in the room. The use of data in real-time can change behavior to reduce exposure.

RaySafe i3 Dosimeter

Figure 7. Dose overview

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The use of a real-time dosimetry system can help visualize the radiation exposure to staff in the room. The use of data in real-time can change behavior to reduce exposure.
Section 10
Radiation Protection Program

Fluoroscopy Safety Training

Section 10, Radiation Protection Program
• A Radiation Protection Program should be developed that is sufficient to comply with regulations and appropriate depending on the scope of the radiation used

• Certain states have specific requirements for the Radiation Protection Program