LANDAUER®
ACADEMY

Fluoroscopy Safety Training

- Section 1: Principles of Radiation Safety
- Section 2: Scatter Radiation
- Section 3: Patient Dose
- Section 4: Dose Reduction Campaigns
- Section 5: Radiation Safety Officer Role
- Section 6: Medical Physicist Role
- Section 7: Physician Role
- Section 8: Technologist Role
- Section 9: Radiation Protection Devices
- Section 10: Radiation Protection Program
- Section 11: Quiz

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

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Section 1
Principles of Radiation Safety

Section One, Principles of Radiation Safety

Fluoroscopy is the use of a continuous X-ray beam to generate medical images in real time

Image credit to Shutterstock

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

Principles of Radiation Safety

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- 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

Fluoroscopy Safety Training

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

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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

Fluoroscopy Safety Training

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

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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

Principles of Radiation Safety

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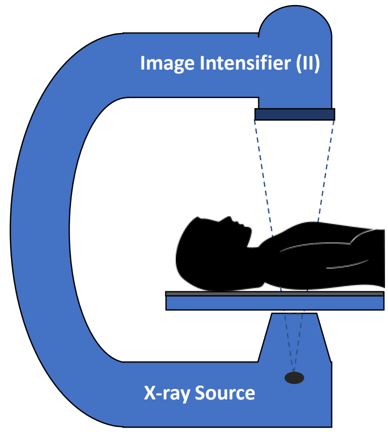
- Patient Distance to X-ray source and Image Intensifier (Detector) is very important
- When the patient is closer to the X-ray source, the patient radiation dose is higher than could be possible.
- The inverse happens when the patient is moved closer to the Image Intensifier. Image quality is improved while radiation dose is lowered



Fluoroscopy Safety Training

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Patient Dose from Various Modalities

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

This is a chart of typical patient dose ranges from various modalities

Principles of Radiation Safety

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Occupational Dose from Various Modalities

Modality	Typical Dose Range
Radiographic	0 to 50 mrem per month
Fluoroscopic/Interventional	25 to 100 mrem per month
Mammography	0 to 2 mrem per month
CT	0 to 100 mrem
Nuclear Medicine-general	10 to 60 mrem per month
PET	50 to 300 mrem per month
MRI	None

Fluoroscopy Safety Training

This is a chart of typical occupational dose ranges from various modalities

Section 2
Scatter Radiation

Section Two, Scatter Radiation

Scatter Radiation

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- 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

Fluoroscopy Safety Training

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

Scatter Radiation

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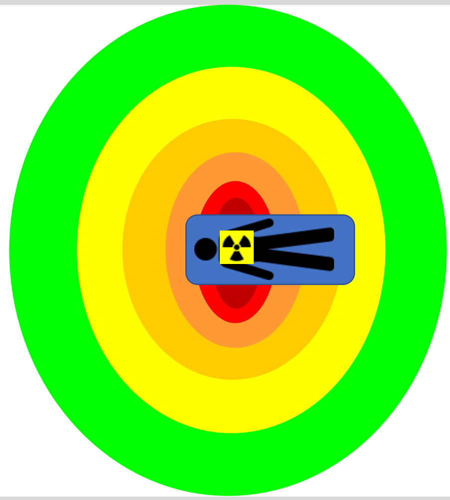
Horizontal Profile of typical scatter map in Fluoroscopy with X-ray tube in the Posterior-Anterior orientation



Fluoroscopy Safety Training

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

Scatter Radiation

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Vertical Profile of
typical scatter map
in Fluoroscopy

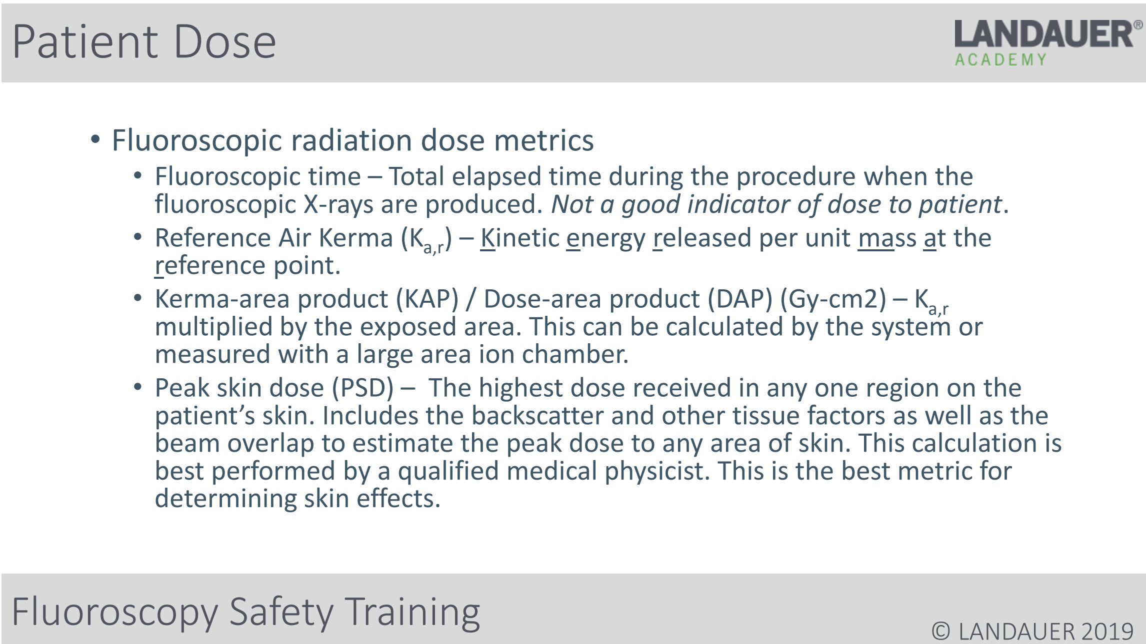
Fluoroscopy Safety Training

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 (Ka,r) – Kinetic energy released per unit mass at the reference point.
Kerma-area product (KAP) / Dose-area product (DAP) (Gy-cm2) – Ka,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.

Patient Dose

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- 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

Fluoroscopy Safety Training

What are the effects of radiation?
Deterministic
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ALARA concept used to minimize the risk

Patient Dose

LANDAUER® ACADEMY

Peak skin dose	Possible deterministic effects
0 – 2 Gy	-
2 – 5 Gy	Transient erythema Temporary epilation
5 – 10 Gy	Prolonged erythema Permanent epilation Dermal atrophy
10 – 15 Gy	Desquamation Telangiectasia
>15 Gy	Acute ulceration Dermal necrosis

Table derived from National Council on Radiation Protection and Measurement (NCRP) Report 168

Fluoroscopy Safety Training

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

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- 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

Fluoroscopy Safety Training

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

Patient Dose

LANDAUER® ACADEMY

- 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

Fluoroscopy Safety Training

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

Patient Dose

LANDAUER® ACADEMY

- 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.

Fluoroscopy Safety Training

Providing information on risks from radiation

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Patient Dose

LANDAUER® ACADEMY

- 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

Dose Metric	First Notification	Subsequent Notifications
Peak Skin Dose (Gy)	2	0.5
$K_{a,r}$ (Gy)	3	1
DAP (Gy cm^2)	300	100
Fluoro Time (min)	30	15

Table derived from NCRP Report 168

Fluoroscopy Safety Training

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. 1/10th 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.

Dose saving techniques

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Dose spreading – When possible, multiple angles can be used to "spread" the dose limiting the skin effects.

Patient Dose

LANDAUER® ACADEMY

- 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

Dose Metric	SRDL
Peak Skin Dose (Gy)	3
$K_{a,r}$ (Gy)	5
DAP (Gy cm^2)	500
Fluoro Time (min)	60

Table derived from NCRP Report 168

Fluoroscopy Safety Training

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

LANDAUER® ACADEMY

- 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

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.

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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.

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

Fluoroscopy Safety Training

How to adjust for a child-size procedure
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Patient Dose

LANDAUER ACADEMY

- 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

Fluoroscopy Safety Training

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

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

LANDAUER® ACADEMY

Take the Image Gently® pledge!

Pledge to Image Gently!®

For group certificates, please click here.

63,902

Pledgers to Date

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

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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

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

Fluoroscopy Safety Training

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

Image Gently® Campaign

LANDAUER ACADEMY

- 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

Fluoroscopy Safety Training

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

LANDAUER® ACADEMY

- 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

Take the Pledge

Fluoroscopy Safety Training

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Section 5
Radiation Safety Officer Role

Section 5, Radiation Safety Officer Role

Radiation Safety Officer Role

LANDAUER® ACADEMY

- 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

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:

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Provide recommendations for improving radiation safety

Intervene as needed to stop unsafe practices

Implement corrective action

Section 6
Medical Physicist Role

Section 6, Medical Physicist Role

Medical Physicist Role

LANDAUER® ACADEMY

- 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)

Fluoroscopy Safety Training

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

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- 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

Fluoroscopy Safety Training

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0.5 cm above the table for under-table X-ray tubes

30 cm from the II for C-arm designs

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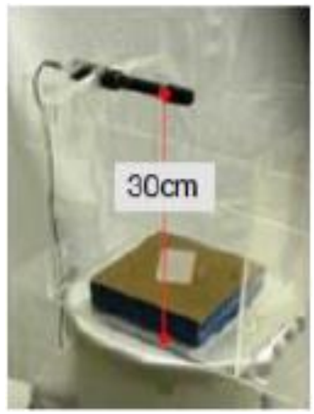
Medical Physicist Role

LANDAUER ACADEMY

Fluoroscopy Testing Setup



Fluoroscopy Safety Training

These are common physics testing configurations

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Section 7
Physician Role

Section 7, Physician Role

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

The physician should be able to identify the point at which image quality starts to drop off

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Section 8
Technologist Role

Section 8, Technologist Role

Technologist Role

LANDAUER® ACADEMY

- 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

Section 9, Radiation Protection Devices

Radiation Protection Devices

LANDAUER ACADEMY

- 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

Fluoroscopy Safety Training

This is a list of external shields you could see in the fluoroscopy suite

Real-Time Dosimetry

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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.

RaySafe i3 Dosimeter

PERSONAL DOSE OVERVIEW – VIEW DETAILED DOSE DATA

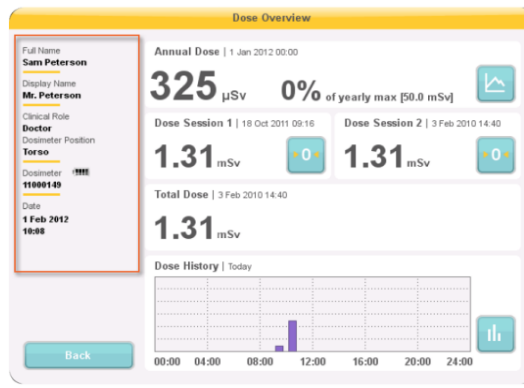

Figure 7. Dose overview

Fluoroscopy Safety Training

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

Section 10, Radiation Protection Program

Radiation Protection Program

LANDAUER® ACADEMY

- 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

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