

Radiation Management for Interventional Fluoroscopy Staff Safety



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Intro

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Working with X-rays

Fluoroscopically guided invasive procedures can be highly effective and beneficial to patients. Unfortunately, the risks of these procedures are imposed on staff as well as on patients. The goal of any kind of safety program is to reduce risks to both regulatory and personally acceptable levels.

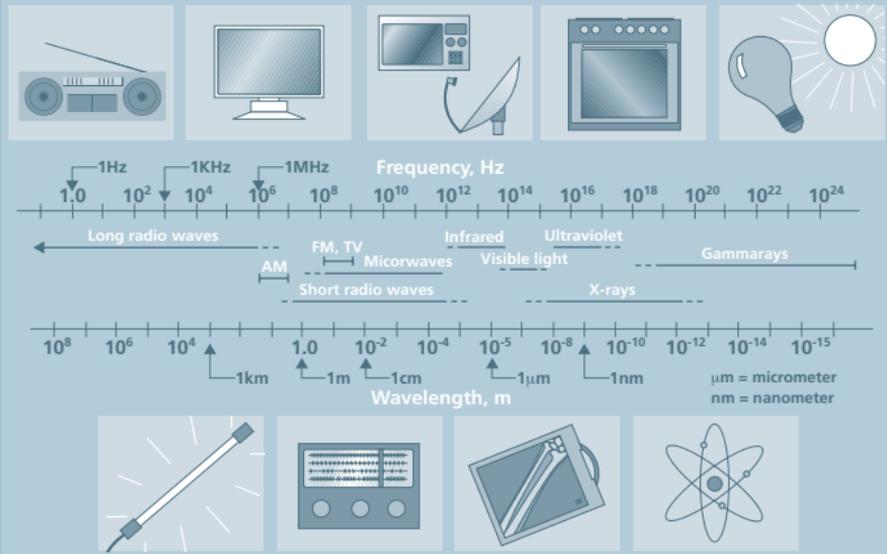
Operators and staff in the interventional laboratory are exposed to many risks. These include ordinary accidents as well as infection, musculoskeletal injury, and radiation injury. This brief booklet only has space to outline some essential facts about radiation safety. More detailed information is readily available in textbooks and in the literature. Local medical physicists or radiation safety specialists also are valuable sources.

Radiation protection regulations and guidelines vary in detail from country to country. The general principle of all of the rules is the same: Maintain the occupational risk of working with radiation to a level similar to safe occupations such as office work.

The overall goal of all radiation management programs is to reduce an individual's exposure to radiation to a level that is As Low As Reasonably Achievable (ALARA). The first major aspect of this program is minimizing or eliminating the unnecessary use of radiation while imaging the patient.

In general, reducing patient irradiation will reduce staff radiation risk. Further information can be found in the companion booklet on managing patient radiation. The second major aspect is minimizing individual risks while working in a radiation environment. This booklet outlines appropriate practice.

What are X-rays?

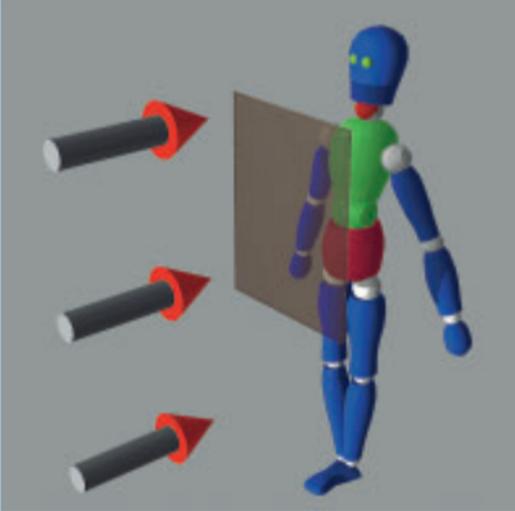


Several kinds of radiation are used in medicine. Fluoroscopic X-rays are composed of photons of different energies. These photons occupy the portion of the electromagnetic spectrum between 10,000 and 150,000 electron volts (10 – 150 KEV). By way of comparison, visible light is between 1.8 and 3.1 electron volts. Infrared photons individually carry less energy than visible light; ultraviolet more, and X-rays much more.

Electromagnetic photons carrying sufficient energy to disrupt molecular bonds (a few electron volts) are called ionizing radiation. Each ionizing radiation photon is capable of permanently disrupting DNA. This can result in cellular transformation or death. Biological processes usually repair most of this damage.

- X-rays are dangerous because a single photon can permanently disrupt DNA.
- Biological repair usually mitigates the clinical effects of this damage.

Radiation Units



This person is exposed to a uniform radiation field. Shielding reduces the dose absorbed by some of tissues relative to others. There is a non-uniform dose distribution.

Effective dose includes both the dose distribution and individual organ sensitivities.

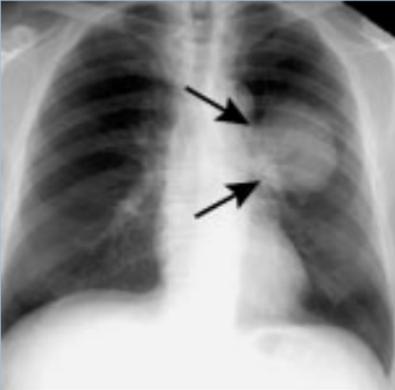
DOSE: The energy deposited in a small mass of a specified material (e.g. muscle) in units of gray (Gy). Dose in the radiological sense (energy/mass) is similar to concentration in pharmacology. **Major skin injuries occur when peak skin dose exceeds 10 Gy.**

AMBIENT RADIATION (EXPOSURE): The energy delivered to a small mass of air at the measurement point. The reported quantity is usually stated as Air KERMA, also measured in Gy (to Air).

EFFECTIVE DOSE: Reports the biological effectiveness of an exposure to radiation (such as cancer induction) in sieverts (Sv). It is obtained by summing the actual dose to each body organ multiplied by a sensitivity weighting factor for that organ.

- EXPOSURE:** Amount of radiation at a point.
- DOSE:** Absorbed energy concentration at a point.
- EFFECTIVE DOSE:** Scaled biological effect on the entire body from an exposure.

Types of Radiation Injury



*Lung Cancer.
This may have been caused
by radiation.*



*Major Skin Injury.
This was caused by
radiation.*

Radiation injuries are divided into two main classifications based on major differences in radiobiology of the underlying event.

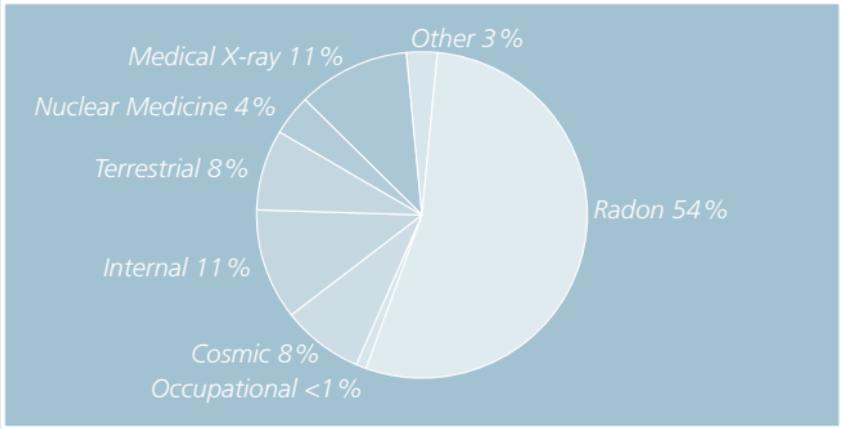
Stochastic Injuries occur when a radiation damaged cell survives the effects of the irradiation and the body's repair processes. When sufficient time passes the mass of descendants of this single cell can become a clinically important disease. The higher the dose, the more likely that this process will occur.

Deterministic Injuries occur when large numbers of cells are damaged to the point where they die immediately or shortly after irradiation. The body can repair the effects of small numbers of destroyed cells. A higher dose destroys more cells and results in a more severe injury.

Stochastic injuries result from unrepaired DNA damage in a single cell. Risk is proportional to dose.

Deterministic injuries result from direct cell killing. Injury is certain if the dose is high enough.

Stochastic Risk



Sources of Radiation Exposure (NCRP)

A single radiation transformed cell can grow into a clinical malignancy. This leads to the conservative Linear-No-Threshold (LNT) risk model. It assumes that any amount of radiation is a hazard and that more radiation increases risk. However, the effects of an effective dose below 100 mSv can not be statistically separated from natural causes. Most interventional staff and many operators receive an occupational effective dose below 1 mSv per year.

Natural background radiation levels provide comparison. A typical nurse living and working in New York City will receive an effective dose of about 3 mSv/y from natural sources. In Denver this increases to about 4 mSv/y. A Denver ski vacation for a CUMC nurse may result in more radiation than working the same days in the lab.

The LNT model predicts a hazard from any level of radiation.

Fluctuations in natural disease levels make it impossible to identify radiation effects below 100 mSv.

Deterministic Injury

Fluoroscopy circa 1915

The X-ray tube is not shielded



Deterministic injuries occur when tissue receives very high doses of radiation. These levels are much higher than those normally experienced by interventional fluoroscopic staff.

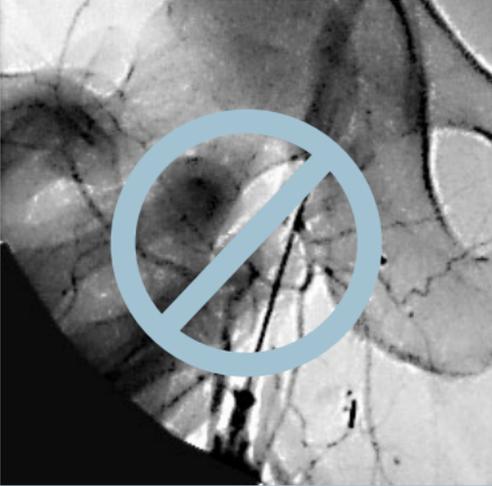
Early (circa 1900) fluoroscopists worked with uncollimated and unshielded systems. Often, they were irradiated by portions of the raw beam outside the patient or used their own hands to tune the X-ray beam. Major injuries occurred.

Reported modern operator injuries include cataract, chronic changes to the skin of the hands, and chronic hair loss to the lower legs. The respective causes were the use of an above table X-ray tube, hands and arms in the raw beam, and a lifetime's exposure to relatively high levels of scatter.

Deterministic Injuries are caused by large dose delivered at the site of injury.

Deterministic injury of radiation workers is an unacceptable consequence of poor radiation hygiene.

Situational Awareness



This operator was not aware that her hands are in the beam during acquisition

There is no radiation unless X-rays are on. In-room lights warn of X-ray production. In some rooms, sounds also serve to alert the staff.

Many rooms have the ability to block X-ray production without affecting other equipment functions. X-rays should always be blocked unless immediately needed.

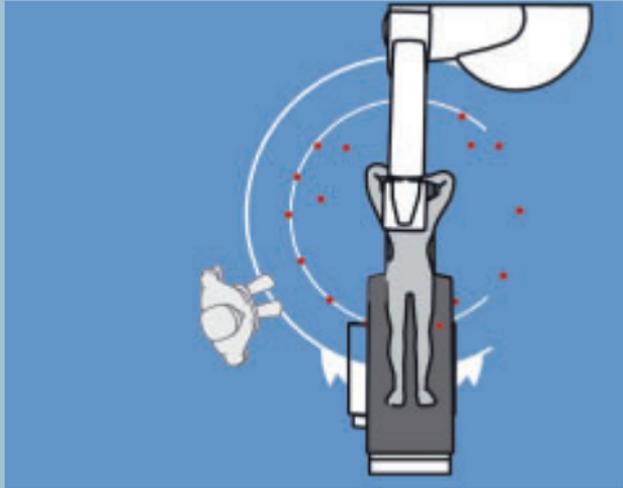
There is much more radiation on the X-ray tube side of the patient than on the image receptor side. Whenever possible work from the image receptor side.

NO BONY FINGERS: Workers should never see their own body parts on the X-ray monitor.

There is no radiation unless X-rays are on.
Operator: Before X-ray – Where are the staff?
Staff: Try to stay back if X-rays are on.

Distance – Operator

The operator has moved away from the patient during acquisition



Operators need to be close to the patient while the X-ray beam is active for some portions of an intervention. However, other portions of the procedure, such as contrast injections, may not require this degree of proximity. Distance from the beam is particularly important during high dose-rate acquisitions such as DSA or cine. When possible, stepping or leaning back from the table will increase the operator's distance from the X-ray beam. This reduces operator dose.

Operators should routinely keep their hands out of the X-ray field. Lead surgical gloves in the beam often increase hand dose. Where avoiding hand exposure is clinically impossible, it is much safer to have the patient's body between the X-ray source and your hands.

Step or lean away from the patient when X-rays are on.

Avoid putting your hands in the beam.

Distance – Staff

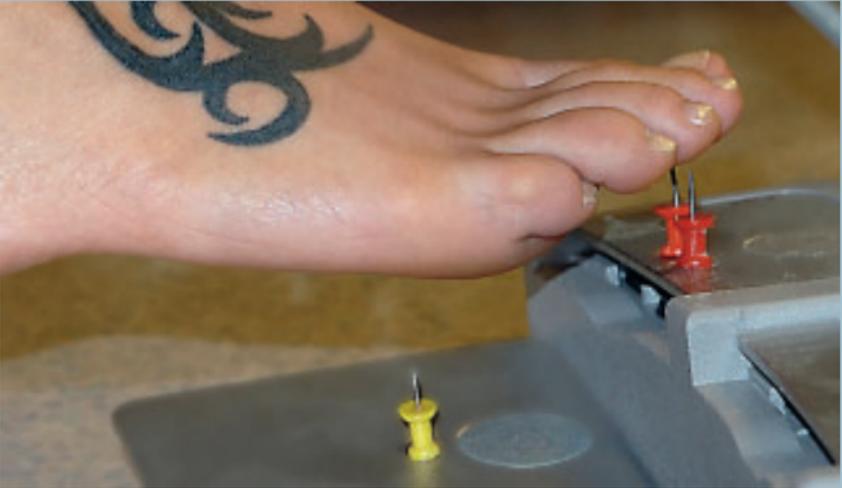


The inverse-square law states that doubling the distance from a point source of radiation cuts the exposure rate by a factor of four. Interventional lab geometry is more complicated. However, A few steps back from the table reduces exposure rates by a factor of two or more. Exposure rates near the walls are often reduced to a few percent of those experienced by operators.

Distance is the radiation safety factor over which staff members have the largest degree of personal control. Staff members should stay as far from the table as they can during most of the procedure. When near the table, the major source of scattered radiation is the point where the X-ray beam enters the patient (beam entry port).

Stay far from the table whenever possible.
Stay as far from the beam entry port as possible.

Time – Operator



Irradiation time is the single radiation protection factor directly under the operator's control. There is no radiation anywhere in the room unless the operator's foot is on the peddle.

X-rays should only be produced when your eyes are on the monitor and you need to observe or document motion.

Last-Image-Hold and Loop-Replay provide means for reviewing parts of a procedure without producing extra radiation. Their routine use is encouraged.

Whenever possible, avoid radiation while staff are close to the patient. This is particularly important if their duties take them close to the X-ray beam.

**The operator causes all the radiation in the lab.
Only irradiate to observe motion.**

Be aware of staff location before irradiating.

Time – Staff



The amber light indicates the active production of X-rays

Minimizing time spent in a radiation field helps minimize exposure. You need to know when radiation is produced and the location of the radiation. When X-rays are on (usually signified by an amber warning light), higher radiation zones are found on the X-ray tube side of the fluoroscope and near the patient.

Do as much as you can when X-rays are off. Let the operator know when you are near the patient. Be certain that X-rays are off in situations such as codes or patient preparation.

Doors to a lab might be open while X-rays are on. Quickly passing an open door results in little exposure. Spending unnecessary time in the doorway without shielding is poor practice.

There is no radiation in the lab unless X-rays are being produced (Look for warning light).

Minimize your time in higher radiation zones.

Personal Shielding



Radiation protective clothing is designed to reduce the wearer's Effective Dose. Shielding only works if it is worn.

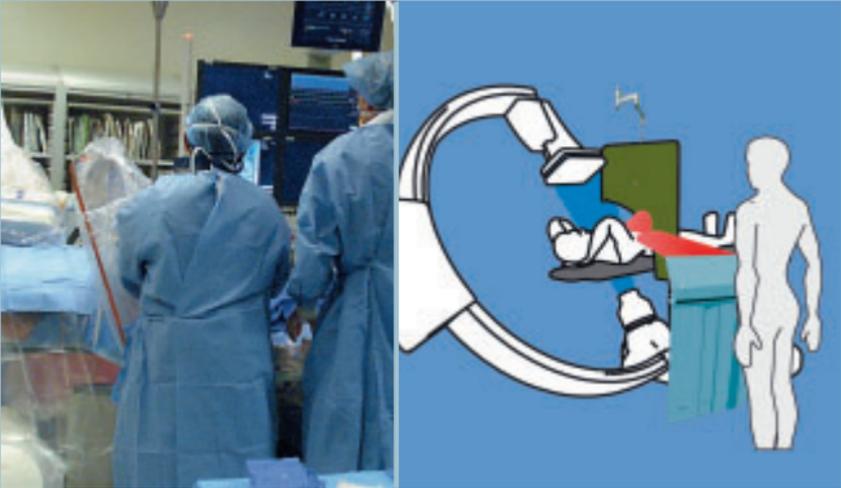
The lead apron (or jacket-skirt combination) protects key central body organs and active marrow. A thyroid shield protects this gland. Shielded eyeglasses should be worn by busy operators and assistants to avoid cataracts.

Increasing the lead thickness beyond recommended values can increase the risk of musculoskeletal injury without substantially reducing radiation risk.

Protective gear should be properly stored when not in use. Their protective value can be reduced if mishandled.

**Protective clothing reduces effective dose.
Use your gear whenever you are in the lab.
Take proper care of it when not in use.**

Shielding



Fixed shielding on walls, doors, and windows reduce exposure outside the lab to appropriate levels (often low enough to permit public access immediately outside the lab).

Local authorities may permit doors to be opened briefly with X-rays on. This is not a hazard unless it is done to excess.

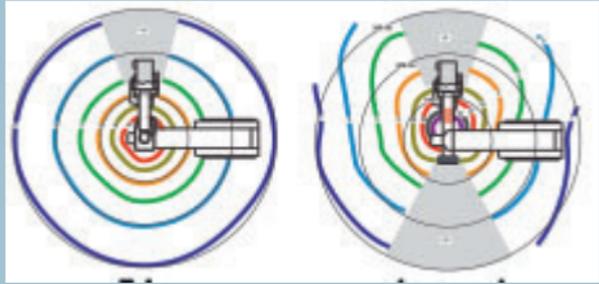
Various shielding devices can be used in the lab to reduce exposure rates behind them. When used, these provide substantial radiation protection without weight on users.

Interventional labs usually have their X-ray tubes under the table to minimize the amount scatter reaching worker's eyes. Table-side drapes provides substantial protection to the feet.

Lab walls, doors, and windows are shielded. Table side, ceiling, and mobile shields substantially reduce exposure rates.

Individual Radiation Monitoring

These isodose curves indicate the variable and complicated radiation environment around the table for PA and Lateral beam orientations



*Relative dose rates
100 cm above floor*

PA: X-ray tube is under the couch. Notice the radiation shadow (top) from the stand

Lateral: X-ray tube is near the top of the page for lateral view

Operators and staff move and work in a complex radiation environment. The only way to assess a person's exposure to radiation is with individual radiation monitors. Also, most facilities provide additional fetal monitors for declared pregnant workers.

Local regulations determine the number and position of the monitors. Each integrates the radiation to which it is exposed. The readings are used to calculate organ and effective dose. For accuracy, monitors must be worn in a consistent fashion.

A set of monitors should be worn by a single individual during working hours. Not wearing the monitors all the time, wearing another person's monitors, wearing monitors while being examined as a patient, and leaving monitors in the lab are examples of practices that result in inaccurate readings.

**Monitors provide evidence of your irradiation.
Wear your monitors when working in the lab.
Protect your monitors when not in the lab.
Never wear someone else's monitors.**

Regulatory Considerations

<i>Tissue</i>	<i>Risk</i>	<i>US Limits</i>	<i>ICRP Limits</i>	<i>Units</i>
<i>Whole Body Stochastic</i>		50	50	<i>max mSv/year</i>
<i>Supplemental Limit</i>		10 x Age	100 in 5 years	
<i>Lens of Eye</i>	<i>Cataract</i>	150 ^d	150 ^d	<i>mGy/year</i>
<i>Extremities</i>	<i>Stochastic^a</i>	500	500	<i>mGy/year</i>
<i>Fetal</i>	<i>Stochastic^b</i>	~2	~1	<i>mSv</i>
<i>Public</i>	<i>Stochastic^c</i>	1	1	<i>mSv/year</i>
<i>Whole Body</i>				

a) Chronic Deterministic injuries, such as hair loss, are possible.

b) Limit is substantially below deterministic threshold.

E to fetus from date of declaration of pregnancy to birth

c) Compare with the natural background level of 3.6 mSv/y.

d) Some research indicates the need for a lower limit.

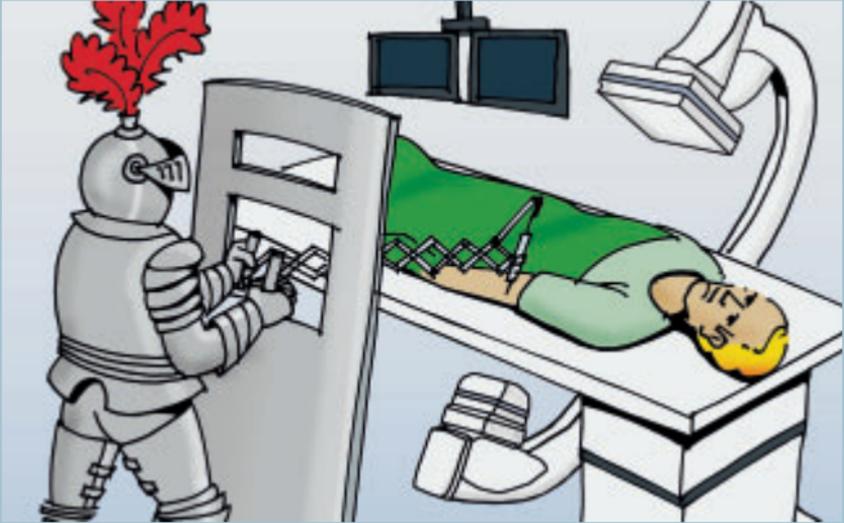
The scientific basis for radiation limits is collected by organizations such as the US National Academy of Science and the UN Commission on the Effects of Ionizing Radiation. Analysis yields the recommended radiation limits shown above.

Because stochastic risks are proportional to dose, radiation work is prudently performed keeping personnel doses As Low As Reasonably Achievable (ALARA). With proper precautions, most workers in an interventional lab receive more than a small fraction of the regulatory limit.

One of the functions of government is limiting public and occupational exposure to toxins such as radiation. Different judgements results in different local radiation protection regulations.

Compliance with regulatory requirements reduces the risks of working with radiation.
Know local rules and regulations.

Radiation Protection Rules



These basic rules should be used to manage the risk of working with all forms of radiation.

DISTANCE:

Increasing the distance between the source of radiation and a staff member decreases dose.

TIME:

STAFF: Reducing the amount of time near the table reduces dose.

OPERATOR: Reducing the amount of time that X-rays are on reduces everyone's dose.

SHIELDING:

The appropriate use of radiation protection garments reduces effective dose.

Web Sites with Additional Information

<http://www.cumc.columbia.edu/dept/radsafety/>

Columbia University Medical Center
Radiation Safety Department – Home Page

<http://dceg.cancer.gov/InterventionalFluor.pdf>

United States National Cancer Institute
Interventional Fluoroscopy

<http://www.acc.org/education/products/products.htm>

American College of Cardiology
Radiation Safety in Cardiology

http://www.icrp.org/docs/Rad_for_GP_for_web.pdf

International Commission on Radiation Protection
General Radiation Information

http://www.icrp.org/educational_area.asp

International Commission on Radiation Protection
Additional Information

www.siemens.com/wbt-dosemanagement

Siemens e-learning website with radiation training



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