RADIATION EXPOSURE
Understanding and Reducing the Risks

Sponsored by:

ORSIF
Organization for Occupational Radiation Safety in Interventional Fluoroscopy

Corindus
Vascular Robotics

Overview and objectives

Interventional therapies offer significant and well-documented life-changing patient benefits. However, exposure to radiation in the work environment can create significant health risks for physicians and their staff, including radiation-related illnesses and orthopedic issues.

After this presentation, you will be able to:

1. Understand the basics of radiation exposure
2. Understand the risks associated with radiation exposure
3. Take action to reduce your exposure to radiation
4. Educate others on the risks associated with radiation exposure and how they can manage these risks

Radiation Exposure Basics

What is medical radiation and why is it important?

Medical Radiation
X-rays and other **ionizing radiation** used to penetrate the body to create images for diagnosis and treatment of medical conditions

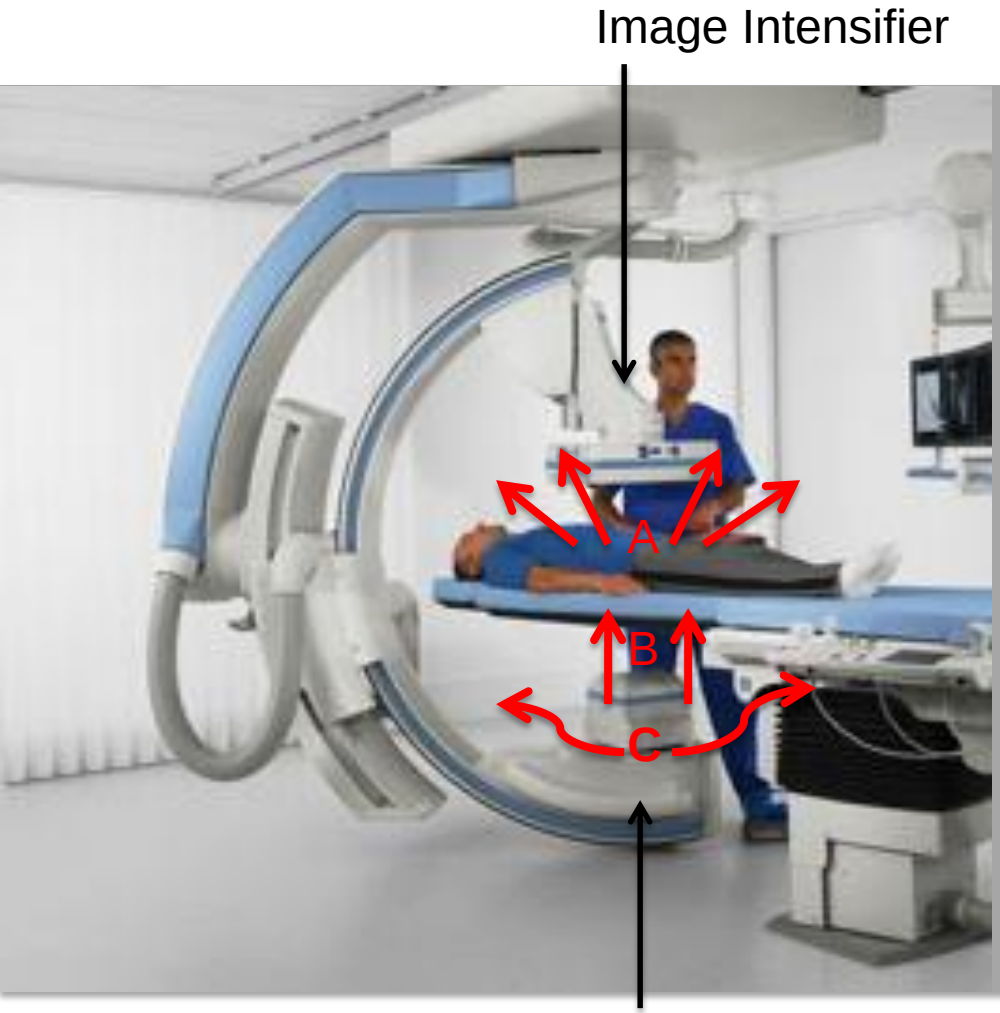
Long-term exposure can lead to gene mutations and increase the risk of cancer <u>if not properly monitored and controlled</u>

Key radiation terms to know

Dose	The quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body
Dosimetry	Act of measuring doses of radiation
Gray (Gy)	Measure of the dose of radiation in terms of the energy absorbed per unit of matter, replaces the older unit designation of RAD • 1 Gy = 100 RAD
Sievert (Sv)	Measure of the health effect of low levels of ionizing radiation on the human body • 2 view chest x-ray is equivalent to 0.1mSv[1]
Roentgen (R)	Measure of radiation in the air
REM (Roentgen equivalent man)	Measure of the dose of radiation in terms of its estimated biological effect relative to a dose of 1 roentgen (r) of X-rays
Frame Rate	Frequency of x-ray image collection during fluoroscopy or cine • Standard fluoroscopy frame rate is 15 frames per second (FPS) • Standard cine frame rate is 30 FPS

1. International Atonic Energy Agency, Radiation Protection for Patients (RPOP) "X-rays: What Patients Need to Know" www.rpopliaea.org

Radiation equipment and exposure sources



Sources of Exposure

A. Scatter radiation from the patient
B. Primary beam radiation exposure
C. Leakage radiation from X-ray tube

Key principles of radiation exposure

Time, distance and shielding

Time	Less imaging = less exposure Ensure benefits of exposure outweigh risks
Distance	As the distance doubles from the radiation source, exposure drops to 1/4th the original dose
Shielding	Lead aprons and shields absorb 90% of radiation Protection of the eyes and thyroid is crucial and often overlooked

Source: IAEA 10 pearls on radiation production of staff in fluoroscopy https://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Posters/fluoroscopy-posters.htm (Accessed February, 5, 2015)

Key principles of radiation exposure

Exposure varies by image intensifier height and angle

- Minimizing the distance between image intensifier and the patient reduces radiation scatter
- **LAO views and steep angulations increase exposure** but may improve visualization[1]
- 60º angulations offer **3x** the exposure of 30º angulations[1]

Choose the Best View

LAO and steep angles can dramatically increase radiation exposure

Operator exposure as a function of x-ray tube angle[2]

		RAO		PA	LAO			
		30º	10º	0º	10º	30º	60º	90º
Cranial	30º	2.3	2.1	2	2.4			
	20º	1.4	1.6	1.5	1.9	3.1	10	
	10º	1.2	1.1	1.1	1.6	2.9	8	9.6
PA	0º	0.8	0.9	1	1.5	2.5	7.3	6.3
Caudal	10º	1.2	1.1	1.1	1.9	2.7	11	6.7
	20º	1.5	1.2	1.3	2.5	3	16	
	30º	1.4	1.8	2.1	3.2			

Darkest shading is ≥3x exposure in PA

1. Beston S, Efstathopolous EP, Katritsis D,Faulkner K,Panayiotakis G. Patient Radiation doses during cardiac catheterization procedures. Br.J. Radiol. 1998 Jun:71 (846):634-9
2. Kuon E, Dahm J, Kmpen K, Robinson, D, Reuter G,, Wucherer, M. Identification of Less-Irradiating Tube Angulations in Invasive Cardiology. J Am Coll Cardiol 2004;44:1420-8

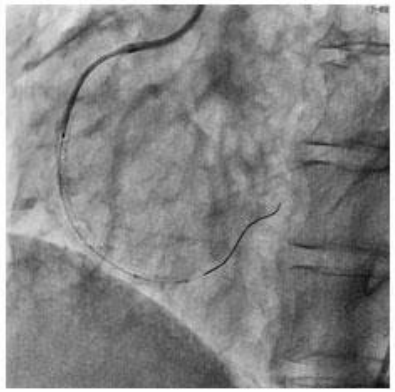
Key principles of radiation exposure

Fluoroscopy equipment features can reduce exposure

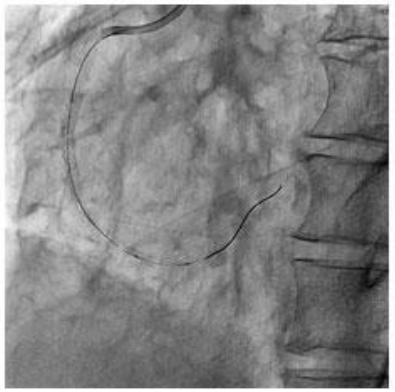
Frame Rate

Lower frame rates decrease radiation exposure, however they can also decrease image resolution

7.5 FPS



15 FPS

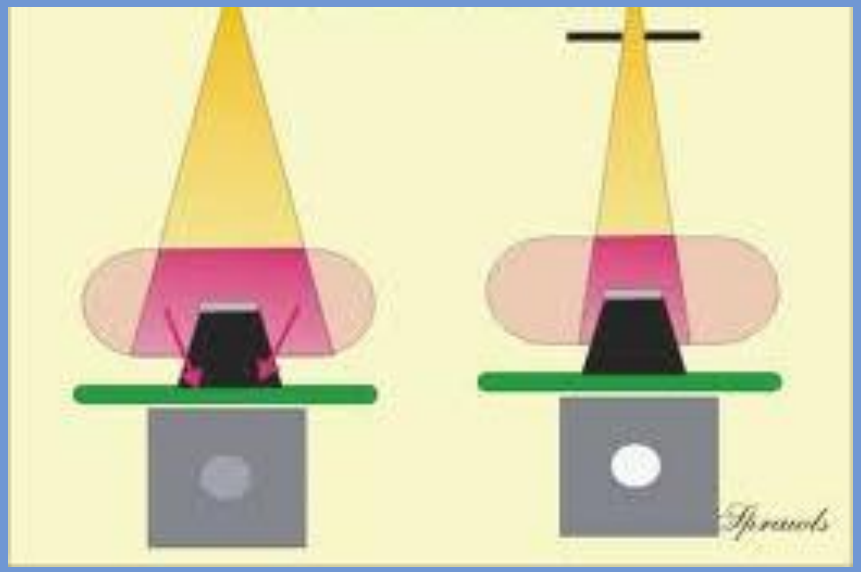


The conventional setting for interventional procedures is 15 FPS

Collimation

Open Beam

Collimated Beam



Collimation focuses the radiation, minimizing unnecessary patient exposure and reducing scatter

Understanding the Risks of Radiation Exposure

Radiation exposure creates significant health risks

With increasing doses of radiation, the risk of cancer increases linearly[1]

Personal protective equipment reduces radiation exposure, however it may cause orthopedic issues[2]

1. International Commission on Radiological Protection. The 2007 Recommendations of the International Commission on Radiological Protection. ICRP publication 103. Ann ICRP (2007) 37:1-332.
2. Goldstein JA, Balter S, Cowley M et al. Occupational hazards of interventional cardiologists: prevalence of orthopedic health problems in contemporary practice. Catheter Cardiovasc Interv 2004; 63:407-211. 15558765

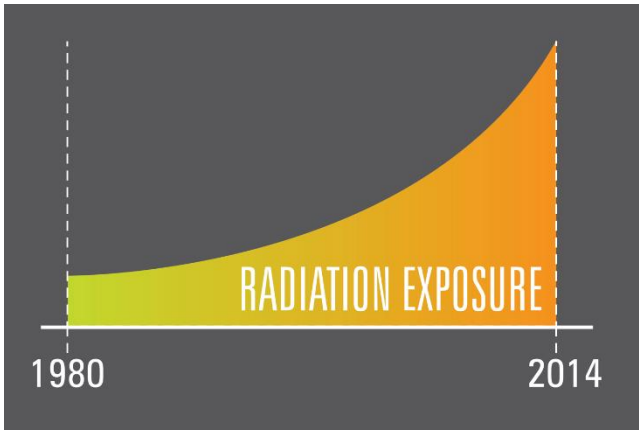
Healthcare professionals are exposed to the harmful effects of radiation every day

Interventional cardiologists (ICs) and their staff are **exposed to high amounts of radiation** due to the long, complicated procedures performed every day and their proximity to the radiation source.[1]

RADIATION EXPOSURE
HAS INCREASED

6X

SINCE 1980



Nearly 40% of the increased exposure is related to cardiovascular imaging and intervention.[2]

1. BÖtticher H et al. Strahlenexposition des Personals im Herzkatheterlabor. Z Med Phys 2003; 13: 251–256
2. National Council on Radiation Protection & Measurements. Ionizing Radiation Exposure of the Population of the United States. Bethesda, MD National Council on Radiation Protection and Measurements, (2009) 160.

ICs and their staff have the highest radiation exposure of any medical profession[1]

Career exposure[2] (Average 20 year IC career)

Exposure	Head	Lower Body
Intensity	1,000 mSv	100 mSv
Equivalence	50,000 Chest X-Rays[3]	5,000 Chest X-Rays[3]

1,000 mSv correlated to a 5% risk of cancer[4]

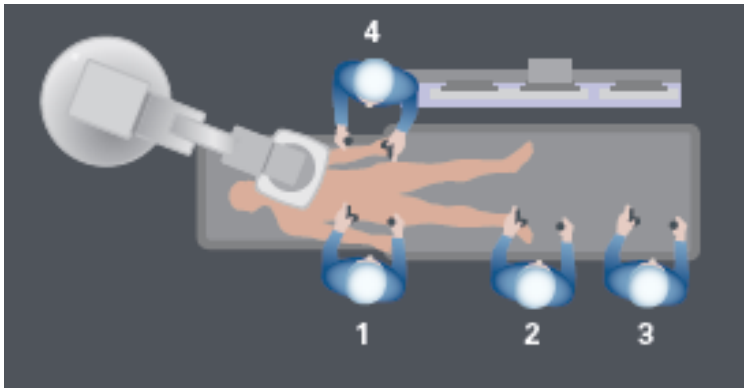
1. Venneri, L et al. Cancer risk from professional exposure in staff working in cardiac catheterization laboratory: Insights from the National Research Council's Biological Effects of Ionizing Radiation VII Report. American Heart Journal, (2009) 157: (1), 118-124
2. Picano, E. et al. Cancer and non-cancer brain and eye effects of chronic low-dose ionizing radiation exposure. BMC Cancer, (2012) 2: (1), 157
3. International Atonic Energy Agency, Radiation Protection for Patients (RPOP) "X-rays: What Patients Need to Know" www.rpopliaea.org.
4. National Council on Radiation Protection and Measurements Limitation of Exposure to Ionizing Radiation. Bethesda, MD: National Council on Radiation Protection and Measurements: No 116 (1993).

Location matters

Personnel location relative to the radiation source changes radiation exposure[1]

Mean Radiation Dose (per procedure) **By Position (*μ*SV)**

Position	1	2	3	4
HEAD LEVEL	18.6	7.86	0.543	73.3
THYROID LEVEL	26.2	12.6	0.746	87.2



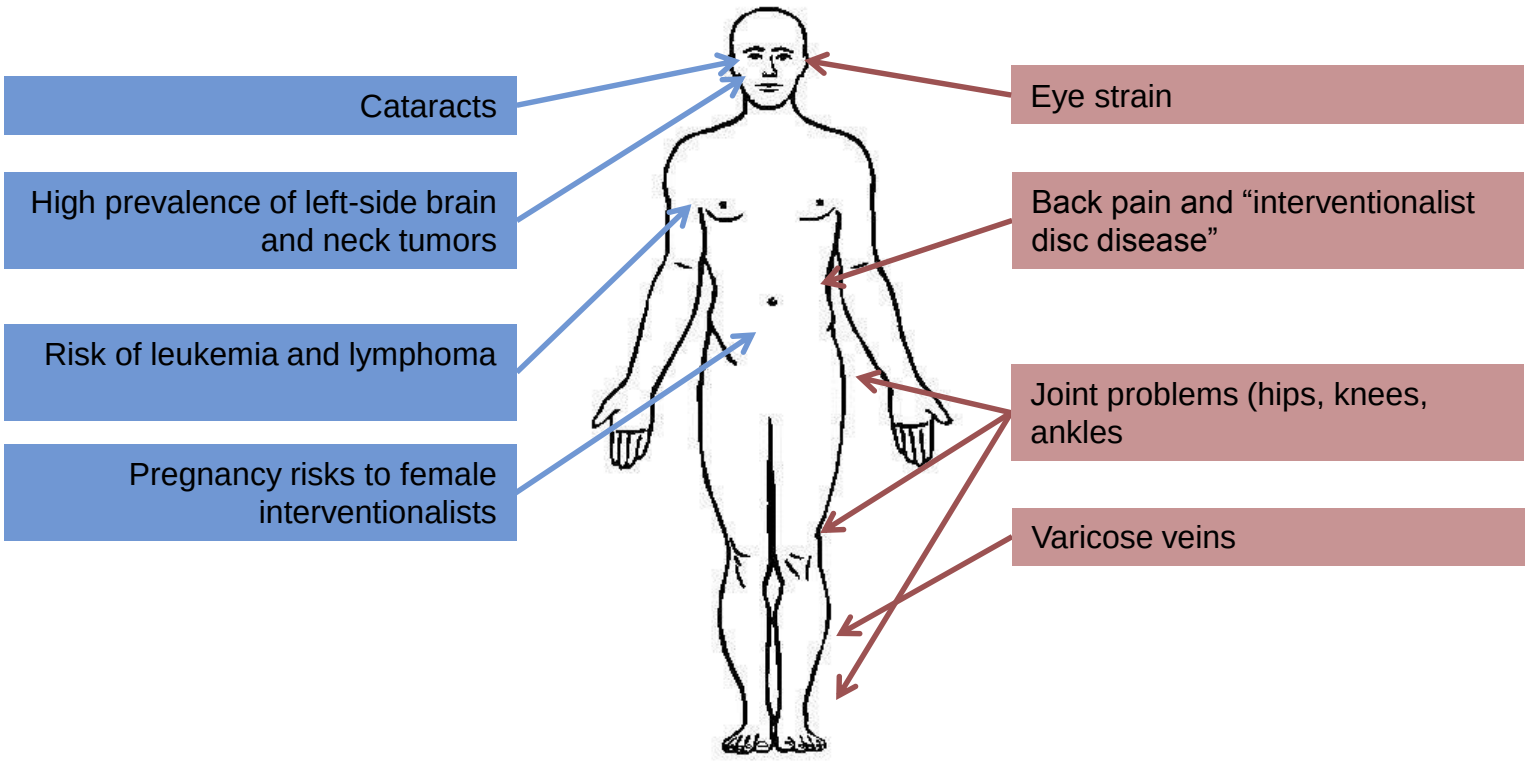
1. BÖtticher H et al. Strahlenexposition des Personals im Herzkatheterlabor. Z Med Phys 2003; 13: 251–256

Impact of radiation exposure

Radiation exposure and the existing tools to reduce radiation exposure can cause significant health concerns

Radiation-Related Impact

Orthopedic Strain



Understanding the risk

Radiation-related impact in interventional cardiology

Cancer

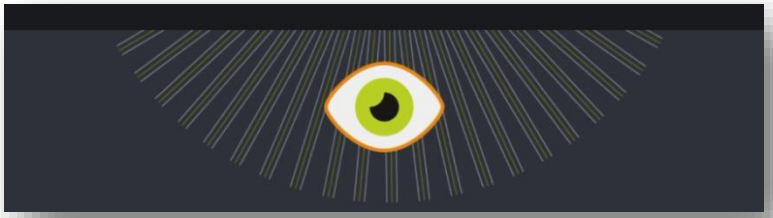
Interventional cardiologists receive **2x the amount of radiation dose on the left side** of their head versus the right[1].

In a study of self-reported brain tumors in interventional physicians, where tumor location is known, **86% of tumors occur on the left side**[1].

Cataracts

41% of nurses and technicians and 50% of interventional cardiologists have significant posterior subcapsular lens changes, a precursor to cataracts[2].

This particular type of opacity is most closely associated with radiation exposure[3].



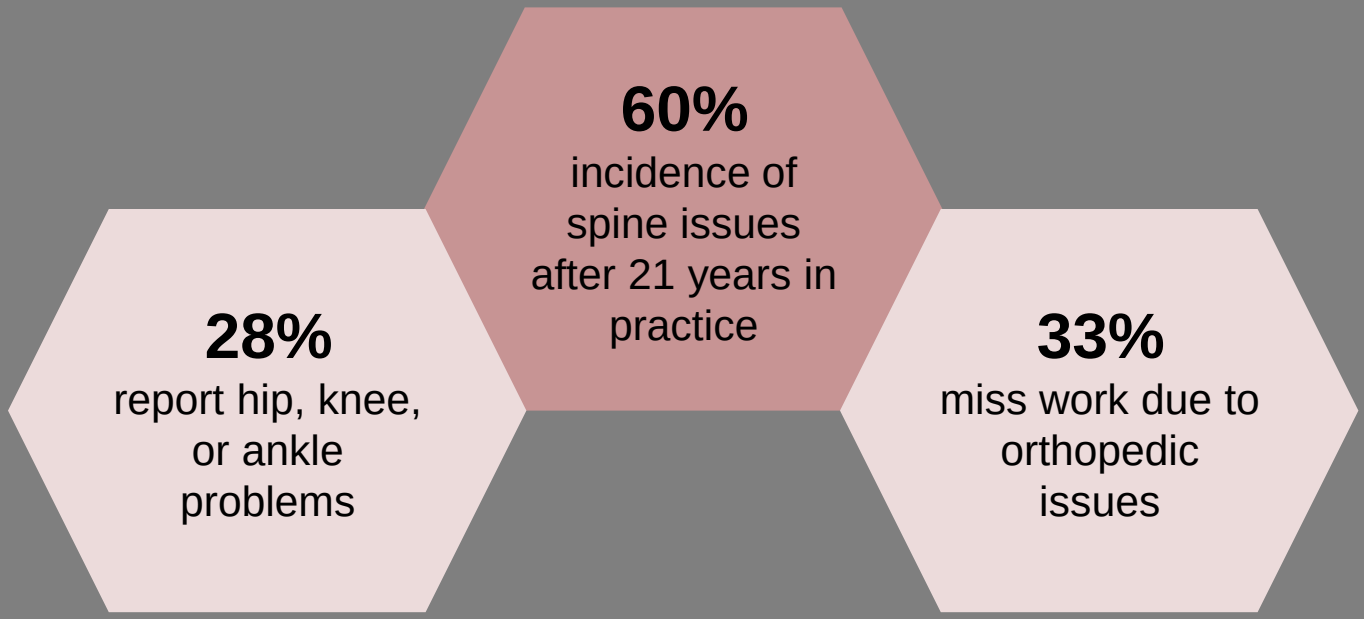
1. Roguin A. Radiation hazards to interventional cardiologists: A report on increased brain tumors among physicians working in the cath lab. SOLACI 2014; April 23, 2014; Buenos Aires, Argentina.
2. E. Vano, et al. *Radiation-associated lens opacities in catheterization personnel: results of a survey and direct assessments.* 24 Journal of Vascular Interventional Radiology 2: 197-204 (2013).
3. Picano, E. et al. Cancer and non-cancer brain and eye effects of chronic low-dose ionizing radiation exposure. BMC Cancer, (2012) 2: (1), 157

Understanding the risk

Orthopedic injury in interventional cardiology

Orthopedic Strain[1,2]

Long days in the cath lab and complex cases increase the time spent in protective equipment, which can create orthopedic strain on the body.



1. Goldstein JA, Balter S, Cowley M et al. Occupational hazards of interventional cardiologists: prevalence of orthopedic health problems in contemporary practice. Catheter Cardiovasc Interv 2004; 63:407-211. 15558765
2. Gregory Dehmer et al., Occupational Hazards for Interventional Cardiologists, The Society for Cardiovascular Angiography and Interventions, 68 Catheterization and Cardiovascular Interventions 974, 975 (2006), http://www.scai.org/asset.axd?id=c01541b7-66c2-46a4-940e-e2a55e71e5bc&t=633945866505100000

Guidelines to manage radiation dose

Guidelines to manage radiation dose

ALARA - As Low As Reasonably Achievable

Provide maximal diagnostic and therapeutic benefit
while requiring the lowest possible radiation dose

Time	Distance	Shielding
• Minimize radiation exposure time • Exposure increases with the amount of time spent near the radiation source	• Maximize distance from radiation source • As distance doubles, exposure decreased by a factor of 4	• Use shielding best practices • Use lead aprons, thyroid collars, radiation glasses, and moveable shields to absorb radiation

Wear dosimeters when in the cath lab to monitor radiation exposure

Solutions to Reduce Radiation Exposure

- Best practices
- Equipment

Best practices for reducing radiation exposure

Procedural Best Practices

- Unessential staff should leave the room during exposure
- Keep hands out of radiation beam
- Keep movable shields in the optimal position at all times
- Maximize distance between operator and radiation source
- Take a step back when imaging

Equipment Best Practices

- Minimize LAO and steep angle projections (≥60^{o})
- Keep x-ray tube under the table
- Minimize use of cine, use last image stored
- Use lowest acceptable frame rate
- Keep the image intensifier close to the patient
- Use collimation to the fullest extent possible

Sources: Chambers CE et al. Radiation safety program for the cardiac catheterization laboratory. Catheter Cardiovasc Interv. 2011 Mar 1;77(4):546-56.
IAEA 10 pearls on radiation production of staff in fluoroscopy https://rpop.iaea.org/RPOP/RPoP/Content/AdditionalResources/Posters/fluoroscopy-posters.htm (Accessed February, 5, 2015)

Equipment for reducing radiation exposure

Several technologies aim to monitor and reduce radiation exposure in the operating suite

Radiation Monitoring Equipment	To monitor radiation exposure during normal operating procedures
Personal Protective Equipment	To minimize radiation exposure during normal operating procedures
Robotic Systems	To provide remote radiation shielded system handling which reduces radiation exposure

Solutions:
Radiation Monitoring Equipment

Radiation monitoring equipment

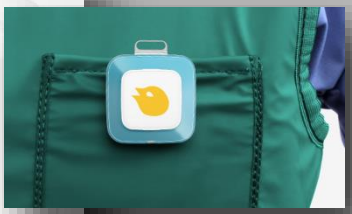
Goal	Designed to monitor radiation exposure
Considerations	Radiation badges must be consistently worn when radiation exposure is possible to ensure accurate monitoring Radiation exposure reports must be reviewed regularly to identify elevated exposure and address overages

Most Common Radiation Monitoring

Dosimeter Badges

Dosimeter Monitoring

Real Time Radiation Monitoring



RaySafe for real-time radiation monitoring

Solutions:
Personal Protective Equipment

- Wearable personal protection equipment
- Stationary protection equipment

Personal protective equipment

Wearable personal protection equipment

Goal	Designed to shield operators from radiation by absorbing x-rays
Considerations	Ergonomic issues should be considered when using lead aprons, as they can cause orthopedic strain when worn for long periods of time.

Most Common Wearable Radiation Protection

Radiation Glasses

Lead Apron

Thyroid Collar

Additional Wearable Radiation Protection

Head Shielding

Zero Gravity

Bloxr Lightweight Lead Caps

Radiation Attenuation Gloves

Personal protective equipment

Stationary personal protection equipment

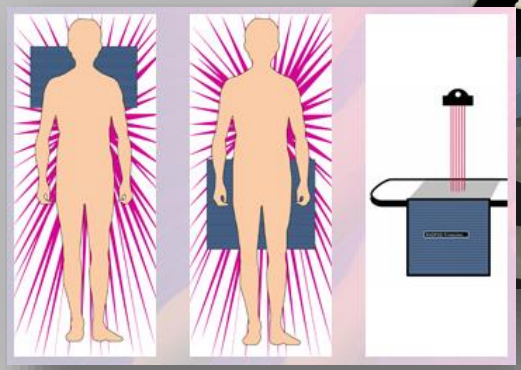
Goal	Designed to shield operators from radiation by absorbing x-rays
Considerations	Depending on room size and layout, stationary shields may be cumbersome

Most Common Stationary Radiation Protection

Movable shields

Additional Stationary Radiation Protection

Trinity Radiation Protection System



Rad Pad

Solutions:
Robotic Assisted Systems

Robotic assisted systems by clinical area

Coronary

CorPath® Vascular Robotic System

Peripheral

Magellan™ Robotic System

Electrophysiology (EP)

The Epoch™ Solution

Sensei® X Robotic Catheter System

Amigo™ Remote Catheter System

Robotic Assisted Surgery

Coronary and peripheral robotic systems

CorPath® Vascular Robotic System

- Robotic system for the treatment of coronary disease
  - Enables precise, robotic-assisted control of coronary guidewires and balloon/stent devices during the angioplasty
- Remote physician workstation
  - Physician seated outside radiation field where lead apron is not required

Corindus Vascular Robotics

Magellan™ Robotic System

- Robotic system facilitates navigation in peripheral interventions
- Remote physician workstation
  - Physician seated outside radiation field where lead apron is not required

hansen™ MEDICAL

Robotic Assisted Surgery

Electrophysiology robotic systems

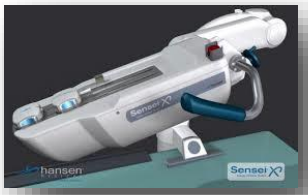
The Epoch™ Solution

- Robotic system facilities navigation in the treatment of arrhythmias and coronary disease
  - Magnetic field used to guide intra-cardiac therapeutic devices (i.e. catheters)
- Remote physician workstation
  - Physician seated outside radiation field where lead apron is not required

STEREOTAXIS

Sensei® X Robotic System

- Robotic system facilitates manipulation and control of mapping catheters in electrophysiology (EP) procedures
  - Primarily used for Afib
- Remote physician workstation
  - Physician seated outside radiation field where lead apron is not required



hansen™ MEDICAL

Robotic Assisted Surgery

Electrophysiology robotic systems

Amigo™ Remote Catheter System

- Robotic system facilities manipulation and control of mapping catheters in electrophysiology (EP) procedures
- Remote physician controller
  - Physician can be seated outside radiation field where lead apron is not required to operate system

Catheter Robotics Inc.

CorPath System designed to reduce radiation exposure and orthopedic strain

Traditional cath lab

Cath lab with CorPath Interventional Cockpit

The CorPath System provides a radiation-shielded work environment in the Interventional Cockpit

- Reducing radiation exposure
- Eliminating the need for lead protection which can reduce orthopedic strain
- Improving ergonomics by allowing cardiologists to sit during the procedure

Summary

Reduce radiation exposure

The risks of radiation exposure are real

ICs and their staff have the highest radiation exposure of any medical profession. Radiation exposure creates significant health risks, including:

- Increased risk of cancer
- Cataracts
- Orthopedic strain from personal protective equipment

You can have an impact

Total procedure radiation dose can be reduced for both staff and physicians with proper training and protective equipment.

- Follow **ALARA** guidelines to manage radiation dose
- Use radiation monitoring equipment
- Use personal protective equipment, including wearable shields and stationary shields
- Consider robotics: Physicians can perform procedures from the comfort and safety of a remote workstation

Exposure today, consequences later

Your exposure today may not be felt for years to come

Radiation-induced cancers have a biological latency of more than 10 years[1]

REDUCING RADIATION EXPOSURE TODAY CAN PREVENT CONSEQUENCES LATER

1. Gerber, T et al. Ionizing Radiation in Cardiac Imaging: A Scientific Advisory from the American Heart Association Committee on Cardiac Imaging of the Council on Clinical Cardiology and Committee on Cardiovascular Imaging and Intervention of the Council on Cardiovascular Radiology and Intervention. Circulation (2009) 119: 1056-65