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
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 if not properly monitored and controlled.
# Key radiation terms to know

<table>
<thead>
<tr>
<th><strong>Dose</strong></th>
<th>The quantity of radiation absorbed, per unit of mass, by the body or by any portion of the body</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dosimetry</strong></td>
<td>Act of measuring doses of radiation</td>
</tr>
<tr>
<td><strong>Gray (Gy)</strong></td>
<td>Measure of the dose of radiation in terms of the energy absorbed per unit of matter, replaces the older unit designation of RAD</td>
</tr>
<tr>
<td></td>
<td>• 1 Gy = 100 RAD</td>
</tr>
<tr>
<td><strong>Sievert (Sv)</strong></td>
<td>Measure of the health effect of low levels of ionizing radiation on the human body</td>
</tr>
<tr>
<td></td>
<td>• 2 view chest x-ray is equivalent to 0.1mSv¹</td>
</tr>
<tr>
<td><strong>Roentgen (R)</strong></td>
<td>Measure of radiation in the air</td>
</tr>
<tr>
<td><strong>REM (Roentgen equivalent man)</strong></td>
<td>Measure of the dose of radiation in terms of its estimated biological effect relative to a dose of 1 roentgen (r) of X-rays</td>
</tr>
<tr>
<td><strong>Frame Rate</strong></td>
<td>Frequency of x-ray image collection during fluoroscopy or cine</td>
</tr>
<tr>
<td></td>
<td>• Standard fluoroscopy frame rate is 15 frames per second (FPS)</td>
</tr>
<tr>
<td></td>
<td>• Standard cine frame rate is 30 FPS</td>
</tr>
</tbody>
</table>

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1. International Atomic Energy Agency, Radiation Protection for Patients (RPOP) “X-rays: What Patients Need to Know” [www.rpopiaea.org](http://www.rpopiaea.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 $1/4^{th}$ the original dose

**Shielding**
Lead aprons and shields absorb 90% of radiation
Protection of the eyes and thyroid is crucial and often overlooked

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 visualization¹
- 60° angulations offer 3x the exposure of 30° angulations¹

### Choose the Best View

**LAO and steep angles can dramatically increase radiation exposure**

Operator exposure as a function of x-ray tube angle²

<table>
<thead>
<tr>
<th></th>
<th>RAO</th>
<th>PA</th>
<th>LAO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>30°</td>
<td>10°</td>
<td>0°</td>
</tr>
<tr>
<td>Cranial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30°</td>
<td>2.3</td>
<td>2.1</td>
<td>2</td>
</tr>
<tr>
<td>20°</td>
<td>1.4</td>
<td>1.6</td>
<td>1.5</td>
</tr>
<tr>
<td>10°</td>
<td>1.2</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>0°</td>
<td>0.8</td>
<td>0.9</td>
<td>1</td>
</tr>
<tr>
<td>PA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10°</td>
<td>1.2</td>
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</tr>
<tr>
<td>30°</td>
<td>1.4</td>
<td>1.8</td>
<td>2.1</td>
</tr>
</tbody>
</table>

Darkest shading is ≥3x exposure in PA

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Key principles of radiation exposure
Fluoroscopy equipment features can reduce exposure

<table>
<thead>
<tr>
<th>Frame Rate</th>
<th>Collimation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower frame rates decrease radiation exposure, however they can also decrease image resolution</td>
<td></td>
</tr>
<tr>
<td>7.5 FPS</td>
<td>Open Beam</td>
</tr>
<tr>
<td>15 FPS</td>
<td>Collimated Beam</td>
</tr>
</tbody>
</table>

The conventional setting for interventional procedures is 15 FPS

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\(^2\)

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.  

RADIATION EXPOSURE HAS INCREASED

6X

SINCE 1980

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

ICs and their staff have the highest radiation exposure of any medical profession¹

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**Career exposure**² (Average 20 year IC career)

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Head</th>
<th>Lower Body</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity</td>
<td>1,000 mSv</td>
<td>100 mSv</td>
</tr>
<tr>
<td>Equivalence</td>
<td>50,000 Chest X-Rays³</td>
<td>5,000 Chest X-Rays³</td>
</tr>
</tbody>
</table>

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1,000 mSv correlated to a 5% risk of cancer⁴

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Location matters

Personnel location relative to the radiation source changes radiation exposure

<table>
<thead>
<tr>
<th>Position</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>HEAD LEVEL</td>
<td>18.6</td>
<td>7.86</td>
<td>0.543</td>
<td>73.3</td>
</tr>
<tr>
<td>THYROID LEVEL</td>
<td>26.2</td>
<td>12.6</td>
<td>0.746</td>
<td>87.2</td>
</tr>
</tbody>
</table>

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

**Radiation-Related Impact**
- Cataracts
- High prevalence of left-side brain and neck tumors
- Risk of leukemia and lymphoma
- Pregnancy risks to female interventionalists

**Orthopedic Strain**
- Eye strain
- Back pain and “interventional disc disease”
- Joint problems (hips, knees, ankles)
- Varicose veins
Understanding the risk
Radiation-related impact in interventional cardiology

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\(^1\).

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\(^3\).

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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.
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.

- 60% incidence of spine issues after 21 years in practice
- 28% report hip, knee, or ankle problems
- 33% miss work due to orthopedic issues

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=63394586650510000
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

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

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

<table>
<thead>
<tr>
<th>Procedural Best Practices</th>
<th>Equipment Best Practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Unessential staff should leave the room during exposure</td>
<td>• Minimize LAO and steep angle projections ($\geq 60^\circ$)</td>
</tr>
<tr>
<td>• Keep hands out of radiation beam</td>
<td>• Keep x-ray tube under the table</td>
</tr>
<tr>
<td>• Keep movable shields in the optimal position at all times</td>
<td>• Minimize use of cine, use last image stored</td>
</tr>
<tr>
<td>• Maximize distance between operator and radiation source</td>
<td>• Use lowest acceptable frame rate</td>
</tr>
<tr>
<td>• Take a step back when imaging</td>
<td>• Keep the image intensifier close to the patient</td>
</tr>
<tr>
<td>• Use collimation to the fullest extent possible</td>
<td>• Use collimation to the fullest extent possible</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Goal</th>
<th>Designed to monitor radiation exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Considerations</strong></td>
<td>Radiation badges must be consistently worn when radiation exposure is possible to ensure accurate monitoring</td>
</tr>
<tr>
<td></td>
<td>Radiation exposure reports must be reviewed regularly to identify elevated exposure and address overages</td>
</tr>
</tbody>
</table>

### Most Common Radiation Monitoring
- Dosimeter Badges
- Occupational Radiation Exposure Report
- 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.

<table>
<thead>
<tr>
<th>Most Common Wearable Radiation Protection</th>
<th>Additional Wearable Radiation Protection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation Glasses</td>
<td>Bloxr Lightweight Lead Caps</td>
</tr>
<tr>
<td>Thyroid Collar</td>
<td>Zero Gravity</td>
</tr>
<tr>
<td>Lead Apron</td>
<td>Radiation Attenuation Gloves</td>
</tr>
</tbody>
</table>
## Personal protective equipment

### Stationary personal protection equipment

<table>
<thead>
<tr>
<th>Goal</th>
<th>Designed to shield operators from radiation by absorbing x-rays</th>
</tr>
</thead>
<tbody>
<tr>
<td>Considerations</td>
<td>Depending on room size and layout, stationary shields may be cumbersome</td>
</tr>
</tbody>
</table>

### 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

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

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
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
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

REDUCING RADIATION EXPOSURE TODAY CAN PREVENT CONSEQUENCES LATER