Risks of Radiation Exposure in Interventional Cardiology

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Basics of Radiation Exposure

Biologic effects of radiation can be broadly grouped as stochastic or nonstochastic effects.

- Stochastic effect is one which the probability of the effect, rather than the severity, increases with dose
- Stochastic effects are believed to lack a threshold dose because injury to a single or a few cells can theoretically result in production of the effect.

Basics of Radiation Exposure

Nonstochastic effect is where the damage is apparent only after reaching a certain threshold dose, meaning that there is zero harm with small radiation doses.

- The severity of damage increases with increasing dose
- Examples: Cataracts, erythema, epilation, death can all result from high radiation exposure.

Common Exposures

Diagnostic

- X-ray machines, including mobile (“portable”) units, fluoroscopes (“C-arms”) and CT scanners.
- Radioactive materials (capsules, liquids, or gases) used in nuclear medicine for diagnostic procedures.
  - Swallowed, intravenous, or inhaled
  - Body fluids from these patients can be radioactive, and caution must be taken when handling them
- Radioactive materials used in the laboratory to perform “in-vitro” or test-tube studies on blood, urine, or cells for the diagnosis of diseases

Procedures with typically extended fluoroscopic exposure time

RF cardiac catheter ablation

Percutaneous transluminal angioplasty

Vascular embolization

Stent/filter placement

Thrombolytic and fibrinolytic procedures

ERCP

TIPS placement

Percutaneous nephrostomy

Biliary drainage or urinary or biliary stone removal

Radiation Exposures during Coronary Angiography and PTCA

Parameter	Coronary Angiography (Diagnostic)	PTCA (Interventional)
Fluoroscopic time (min)	4.5 (2.9, 8.2)	21.9 (14.4, 33.2)
Cine time (min)	0.7 (0.5, 0.9)	1.4 (1.1, 2.0)
Fluoroscopic exposure (mGy)	290 (170, 510)	1,880 (1,150, 2,900)
Cine exposure (mGy)	950 (600, 1,340)	1,740 (1,130, 2,530)
Total exposure (mGy)	1,350 (900, 1,910)	3,760 (2,400, 5,560)

Radiographic Equivalencies of Receptor Entrance Exposures for Various Fluoroscopic Imaging Modes

		Equivalent No. of Radiographs	
Operational Mode	REE* per Image (nC/kg)	Film†	Digital Photospot‡
Normal fluoroscopy§ for 1 min	0.52 (2)‖	12	36
High-dose fluoroscopy§ for 1 min	1.55 (6)‖	36	108
Cine fluoroscopy§ run for 1 min	3.87 (15)‖	90	270
Digital subtraction angiography#	258 (1,000)‖	333	1,000

Maximum Occupational Exposure

The effects of cumulative lifetime exposures smaller than approximately 100 mSv in occupational workers, exposed to low levels of radiation, did not lead to radiation-related adverse health effects in the most reliable studies available

Maximum tolerated effective dose via occupational exposure: US National Council on Radiation Protection and Measurements (NCRP)

- 50 mSv / year
- 100 mSv / 5 years

The average annual effective dose for all occupational workers is less than 10 percent of the 50 mSv limit, and most radiation workers receive less than 10 mSv per year

Maximum tolerated effective dose via occupational exposure: International Commission on Radiological Protection (ICRP)

- 20mSv per year occupational effective dose limit
    - May go as high as 50 mSv per year provided that the average annual dose over five years is 20 mSv or less.
- Worker’s lifetime cumulative dose: < 1 Sv.

Maximum Occupational Exposure

Both the NCRP and ICRP assume that the exposure to professionals is being done while they are exercising various protective measures such as lead aprons covering the trunk and thyroid.

The study compared the radiation exposure during pedicle screw implantation procedures in (a) a robot-assisted, minimally invasive approach, versus (b) open approach, relying on 2D fluoroscopy for guidance and verification.

They calculated that on average, the maximum occupational exposure limit of 100 mSv annually is surpassed after...

1,600 surgeries per year using an open approach,

the equivalent of about 16 years of work for a surgeon performing 100 surgeries a year.

3,900 surgeries per year using robotic guidance in a minimally invasive approach

the equivalent of about 39 years of work of performing 100 surgeries a year.

Effective Dose of Common Procedures

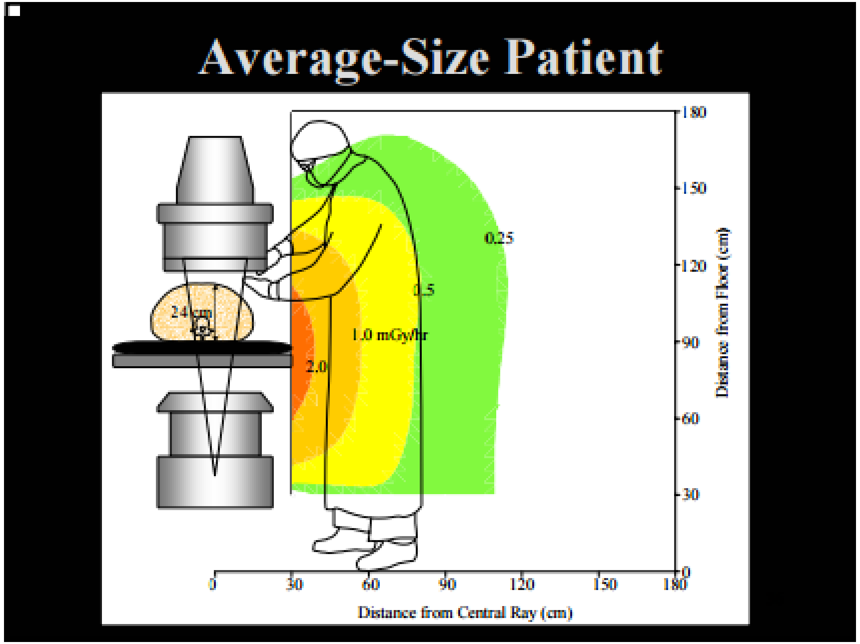
Average U.S. natural background dose	3 mSv / year
Chest X-ray	0.1 mSv
Chest CT (standard)	7.0 mSv
Diagnostic coronary angiogram	7.0 - 10.0 mSv
PTCA	7.0 - 20.0 mSv

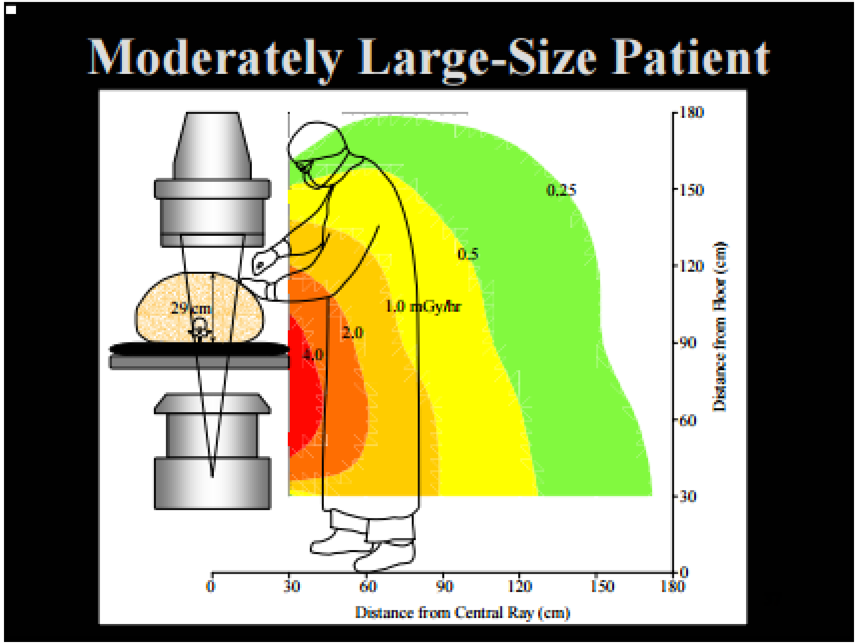
Effective dose 1 mSv = Exposure dose 1 mGy

Radiation Exposure to Staff During Fluoroscopy

- For every 1000 photons reaching the patient, about 200 are scattered, 20 reach the image detector, and the rest are absorbed
- The main source of exposure to staff is **scattered radiation** from the patient
- Exposure is determined by
  - Distance from patient (inverse square law)
  - Height of staff
  - X-ray tube position
  - Irradiated patient volume
  - Characteristics of the radiation beam

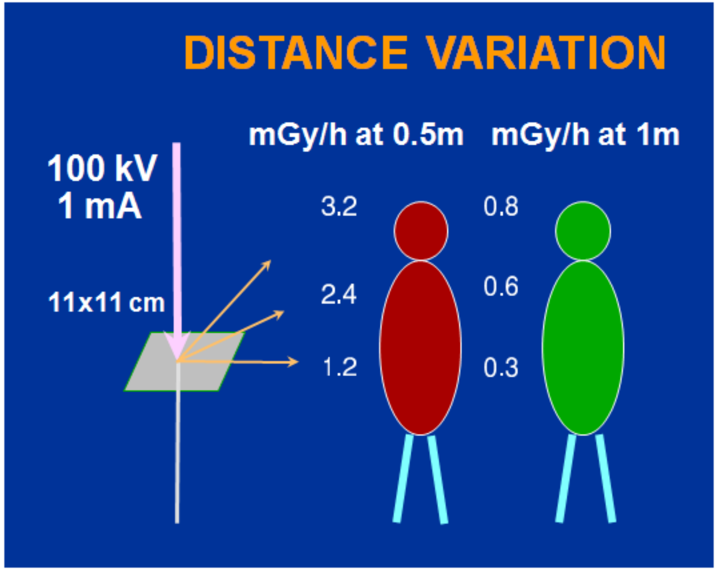
Radiation Exposure to Staff During Fluoroscopy





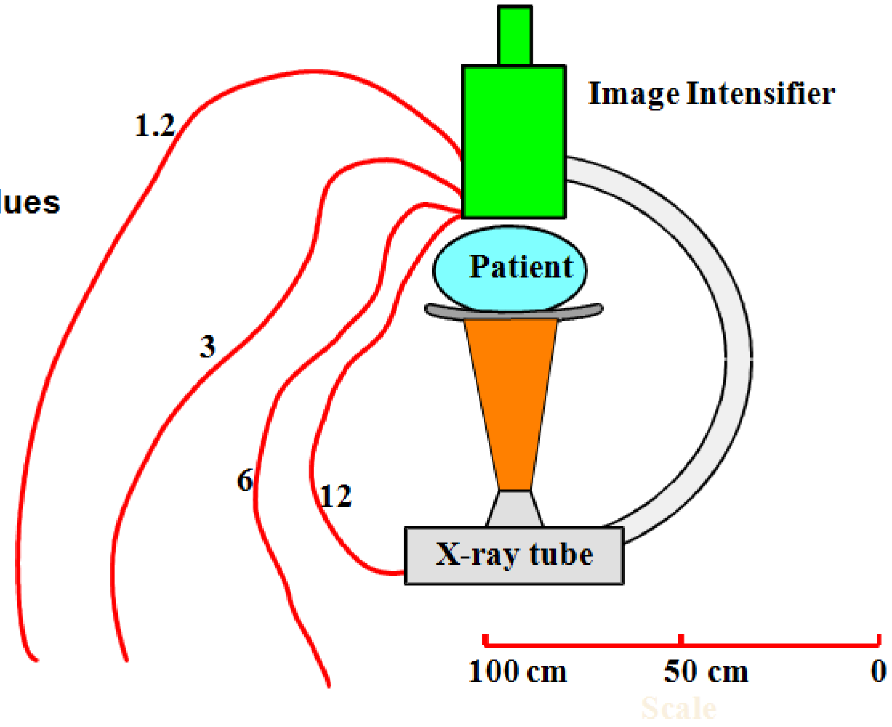
International Atomic Energy Agency

At the level of the patient, for a field size of 11 cm x 11 cm with a beam of 100 kV at 1 mA, the effective dose is approximately 0.3 mGy/hour at 1 meter



International Atomic Energy Agency

All Contour values in µGy/min



At 4 ft (125 cm), average effective dose is 72 uGy/hr

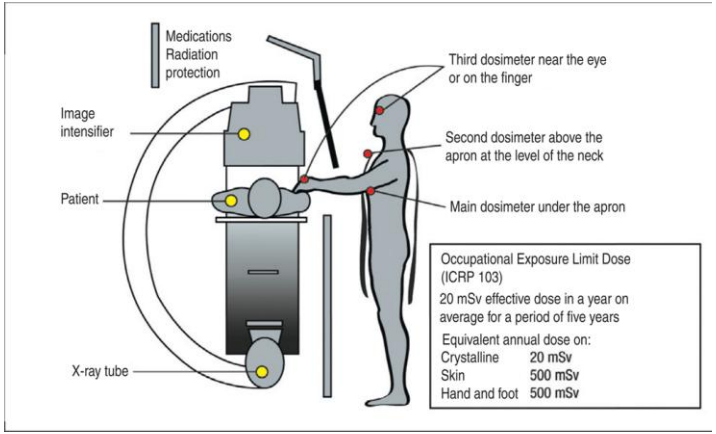
Mean Effective Dose for Interventional Cardiologists

- Kim et al. 2008. Occupational radiation doses to operators performing cardiac catheterization procedures.
- “All English-language journal articles from diagnostic or interventional fluoroscopically-guided cardiovascular procedures from the early 1970’s through 2008”

Diagnostic Catheterizations	0.02-0.38 uSv
PCI	0.17-31.2 uSv
Ablations	0.24-9.6 uSv
Pacemaker/ICD implantations	0.29-17.4 uSv

Mean Effective Dose for Interventional Cardiologists

- Study of 9 cardiologists during 144 procedures (PCI) in 2 Greek hospitals
- Mean effective dose values 1.2-2.7 uSv
- Maximum annual dose estimated to be 1.9-2.8 mSv



Staff Risks

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“Sought to determine whether the prevalence of work-related cancer and other medical conditions is higher among physicians and allied staff who work in interventional laboratories compared with employees who do not”

Increased prevalence of musculoskeletal pain

No difference in cancer prevalence between groups

Staff Risks

Italian Society of International Cardiologists and Cardiac Electrophysiologists, 466 physicians, nurses, technicians

Exposed personnel had higher rates skin lesions, cataracts, hypertension, hyperlipidemia in exposed vs nonexposed group

However, increased risk clearly favoring primary operators with increased age and longer history of work

Median *lifetime* effective dose of nurses approximately 7 mSv

Protection Against Radiation

Minimize Time

Maximize Distance

As the distance from a radiation source increases, the radiation exposure decreases rapidly. Doubling the distance between a person and the radiation source reduces the radiation exposure to as little as one-fourth (1/4) of the original exposure.

Maximize Shielding

All individuals present in the X-ray room during an exposure must be protected from the primary beam by at least 0.5 mm lead equivalency and from scatter radiation by at least 0.25 mm lead equivalency.

Access to the X-ray room must be secured during the exposure.

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