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## PATIENT RADIATION SAFETY AND RISK

### Objectives:

1. Understand the difference between nonionizing and ionizing radiation
2. Understand the difference between stochastic and non-stochastic effects
3. Be able to discuss the concept of ALARA

Everyone is concerned about patient radiation dose. From 1993 through 2008, radiation dose attributed to medical radiation rose from 0.54 mSv to 3 mSv per capita. The largest component of the medical patient radiation dose was CT scanning (49 %). This is despite the fact that CT scanning makes up only 17 % of the total medical procedures that contributes to a patient's radiation dose.

Radiation dose for all diagnostic exams should be minimized to the lowest amount of radiation needed to produce a diagnostic quality exam.

### What Is Radiation?

Radiation is emitted from unstable atoms. Unstable atoms are said to be “radioactive” because they release energy (radiation). The radiation emitted may be electromagnetic energy (x-rays and gamma rays) or particles such as alpha or beta particles. Radiation can also be produced by high-voltage devices, such as x-ray machines. X-rays are a form of electromagnetic energy with a wavelength that places it into an ionizing radiation category. In a diagnostic exam, these photons can penetrate the body and are recorded on digital or film medium to produce an image of various densities that show details inside the body.

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Light, radio, and microwaves are nonionizing types of electromagnetic radiation. Radio waves are used to generate MR images. X-rays and gamma rays are *ionizing* forms of electromagnetic radiation and can produce charged particles (ions) in matter. When ionizations occur in tissue, they can lead to cellular damage. Most damage is repaired by natural processes. In some cases, the damage cannot be repaired or is not repaired correctly which can lead to biological effects.

There are two categories of biological effects related to radiation exposure:

Non-stochastic (also called deterministic)

Stochastic (also called probabilistic)

- *Non-stochastic* effects can occur when the amount of radiation energy imparted to tissue (dose) exceeds a threshold value. Below the threshold, no effect is observed. Above the threshold, the effect is certain.

Examples:

- Skin injury
- Cataracts
- Stochastic effects can manifest at any dose, meaning there is no threshold below which the effect cannot occur. In reality, the probability of a stochastic effect increases as radiation dose imparted to the tissue increases.

Examples:

- Cancer
- Leukemia

## Where Do We Use Radiation in a Hospital?

Radiography:

- Fluoroscopy
- Mammography
- Cardiac catheterization
- Computed tomography
- Radiation therapy (linear accelerator)

Radioactive material:

- Nuclear medicine
- Radiation therapy

Listed below are three tables they provide an estimate of effective radiation dose from common diagnostic exams and interventional procedures (Tables 1.1, 1.2, and 1.3). As a reference standard, the average annual background radiation we all receive from the sun and soil is 3 mSv.

**Table 1-1** Typical effective radiation dose from diagnostic x-ray-single exposure (Adapted with permission from Mettler et al. 2008)

Exam (Mettler et al. 2008)	Effective dose mSv (mrem)
Chest	0.1 (10)
Cervical spine	0.2 (20)
Thoracic spine	1.0 (100)
Lumbar spine	1.5 (150)
Pelvis	0.7 (70)
Abdomen or hip	0.6 (60)
Mammogram (2 view)	0.36 (36)
Dental bitewing	0.005 (0.5)
Dental (panoramic)	0.01 (1)
DEXA (whole body)	0.001 (0.1)
Skull	0.1 (10)
Hand or foot	0.005 (0.5)

**Table 1-2** The dose a patient could receive if undergoing an entire procedure that may be diagnostic or interventional. For example, a lumbar spine series usually consists of five x-ray exams (Adapted with permission from Mettler et al. 2008)

Examinations and procedures	Effective dose mSv (mrem)
Intravenous pyelogram	3.0 (300)
Upper GI	6.0 (600)
Barium enema	7.0 (700)
Abdomen, kidney, ureter, bladder (KUB)	0.7 (70)
CT head	2.0 (200)
CT chest	7.0 (700)
CT abdomen/pelvis	10.0 (1,000)
Whole-body CT screening	10.0 (1,000)
CT biopsy	1.0 (100)
Calcium scoring	2.0 (200)
Coronary angiography	20.0 (2,000)
Cardiac diagnostic and intervention	30.0 (3,000)
Pacemaker placement	1.0 (100)
Peripheral vascular angioplasties	5.0 (500)
Noncardiac embolization	55.0 (5,500)
Vertebroplasty	16.0 (1,600)

**Table 1-3** Typical effective radiation dose from nuclear medicine examinations (Adapted with permission from Mettler et al. 2008)

Nuclear medicine scan radiopharmaceutical (common trade name)	Effective dose mSv (mrem)
Brain (PET) 18F FDG	14.1 (1,410)
Brain (perfusion) 99mTc HMPAO	6.9 (690)
Hepatobiliary (liver flow) 99mTc sulfur colloid	2.1 (210)
Bone 99mTc MDP	6.3 (630)
Lung perfusion/ventilation 99mTc MAA & 133Xe	2.5 (250)
Kidney (filtration rate) 99mTc DTPA	1.8 (180)
Kidney (tubular function) 99mTc MAG3	2.2 (220)
Tumor/infection 67Ga	2.5 (250)
Heart (stress-rest) 99mTc sestamibi (Cardiolite)	9.4 (940)
Heart (stress-rest) 201Tl chloride	41.0 (4,100)
Heart (stress-rest) 99mTc tetrofosmin (Myoview)	11.0 (1,100)
Various PET Studies 18F FDG	14.0 (1,400)

## What Are the Risks?

There is no threshold for stochastic effects so any imaging procedure or therapy that involves the use of radiation involves some risk. When performed properly, the risk is usually very small and is far outweighed by the medical benefit of having the procedure. Regardless, the concept of ALARA (keeping the radiation dose as low as reasonably achievable) should always be employed to minimize the risk.

A small percentage of imaging and therapy studies performed in the hospital can potentially exceed threshold values for non-stochastic effects.

Radiation therapy and interventional fluoroscopy procedures may result in radiation doses that exceed the threshold dose for skin injuries, and less frequently for cataract induction. The procedures performed in these areas are often lifesaving, and every effort to minimize the magnitude of these effects is taken.

## Resources

As you continue your career in medicine, you will specialize. Part of medicine, in virtually all areas of specialization, involves ordering x-rays or nuclear procedures for your patients.

In the news media, great attention has been paid to the increase in medical radiation dose to members of the public. Currently, there are discussions and debates

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over the appropriateness of ordering certain exams without need. This will become a health system financial restraint as well as a public health question.

Some Resources to Look into:

ACR Appropriateness Criteria

[http://www.acr.org/secondarymainmenucategories/quality\\_safety/app\\_criteria.aspx](http://www.acr.org/secondarymainmenucategories/quality_safety/app_criteria.aspx)

Image Wisely Campaign (adult)

[http://www.rsna.org/Media/rsna/upload/Wisely\\_525.pdf](http://www.rsna.org/Media/rsna/upload/Wisely_525.pdf)

Image Gently Campaign (pediatrics)

<http://www.pedrad.org/associations/5364/ig/>

Health Physics Society

<http://hps.org/physicians/blog/>

<http://hps.org/publicinformation/asktheexperts.cfm>

## References

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