Pregnancy Toolkit

Society of Interventional Radiology

Radiation exposure: Basic facts

Interventional radiologists are exposed to radiation from photons generated by the X-ray tube in the angiography suite as well as scatter radiation during CT-guided procedures, especially while using CT fluoroscopy. The effect of radiation exposure to tissue is primarily related to the direct or indirect damage it can cause to deoxyribonucleic acid, DNA. Direct damage to a DNA strand may break or damage it. Intrinsic DNA repair mechanisms can allow DNA to be repaired by the body without sequelae but abnormal DNA repair can lead to nonviable cells. Additionally, translocations of the DNA strand that occur during repair may drive the expression of oncogenes, which could increase the risk of development of future malignancies or heritable genetic defects.

The most radiosensitive tissues are those with the highest mitotic activity, such as skin, bone marrow, thyroid, thymus, gonads, the lens of the eye and fetal tissue. Effects of radiation exposure are categorized as either stochastic effects or deterministic effects. Stochastic effects occur with no radiation dose threshold and the probability of an effect increases with increased dose (linear, no threshold hypothesis) and include the risk of development of cancer. The risk of developing a cancer related to radiation exposure is thought to follow a linear pattern; however, the age at exposure and the exposed tissue are also important determinants of risk. Deterministic effects of radiation exposure occur above a threshold of exposure with increased severity with increasing dose above the threshold. No effects are seen below the threshold exposure. Examples of deterministic effects of radiation exposure are listed in the table below.

Deterministic Effects

Radiation effect	Gestation (weeks)	Threshold dose (mrem)
Embryonic death	3-4	10,000-20,000
Major Malformations	4-8	25,000-50,000
Growth retardation	4-8	20,000-50,000
Irreversible whole body growth retardation	8-15	25,000-50,000
Severe mental disability	8-15, >16	6,000-50,000, >150,000
Microcephaly	8-15	>2 million
Decrease in IQ	>16	>10,000

SOURCE: https://www.ncbi.nlm.nih.gov/pubmed/22112899/

For the pregnant IR, the most concerning deterministic effects are intrauterine growth retardation, teratogenesis and fetal death (usually the product of very high radiation exposure, with a threshold dose >20 Gy).[1] The mean effective dose for U.S. medical workers in 2006 was 0.75mSv (0.00075 Gy)[2], which is magnitudes below this deterministic level. The risk of tissue reaction or deterministic effect to an embryo or fetus is very low due to low radiation exposure, typically less than 100 mGy.[2] Deterministic risks are higher during phases of rapid cell turnover, which is greatest at preimplantation and organogenesis in the first trimester with relative decrease in risk from the second to third trimester of pregnancy. Studies have not demonstrated any increased risk of cancer in the offspring of medical radiation workers.[3]

Regulatory dose limits are established to minimize probable risk and prevent deterministic risk, as listed on the table below. Radiation exposure is strictly monitored for all radiation workers. IR physicians are monitored monthly with a dosimeter worn outside the lead on the thyroid collar with additional badges sometimes employed on the inside of the lead shield's waist and/or a ring badge. Once a pregnancy is declared, an additional badge is worn on the waist under the lead shielding for increased monitoring of fetal dose.

U.S. Nuclear Regulatory Commission Occupational Dose Limits

Whole body (TEDE)	5,000 mrem/yr
Any organ (TODE)	50,000 mrem/yr
Skin (SDE)	50,000 mrem/yr
Extremity (SDE)	50,000 mrem/yr
Lens of eye (LDE)	15,000 mrem/yr
Embrio/Fetus of DPW	500 mrem/yr
Member of the public	100 mrem/yr

Note: 1,000 mrem = rem

Studies performed by various subspecialty groups, including vascular surgery, interventional radiology and interventional cardiology, report fetal exposure dosimeter readings to be negligible.[4, 5] A prospective study by Marx et al. examining doses obtained under and over lead aprons in 30 IRs over two months demonstrated mean projected monthly deep dose equivalent to be 9 mrem under a 0.5-mm lead apron at the waist and 3 mrem under a double-lead 1.0-mm apron.[4] Hence the average dose to a pregnant IR who works throughout the entire 40-week pregnancy wearing double lead is about 30 mrem, which is well below the occupational fetal dose limit of 500 mrem. Additional studies have shown that procedures using beta-particles (i.e., Y-90 radioembolization) confer no known additional risks to the fetus.[4] While the concern of radiation exposure and its effects during and after pregnancy is legitimate, there are safety guidelines and precautions that female IRs can employ to perform IR treatments with minimal risk during pregnancy.

Key points

- IRs are exposed to radiation from photons generated by the X-ray tube in the angiography suite as well as scatter radiation during CT-guided procedures, especially while using CT fluoroscopy.
- Effects of radiation exposure include:
  - » Stochastic effects:
    - › Cancer risk
    - › No radiation dose threshold
    - › Linear increase of risk with increased dose
  - » Deterministic effects:
    - › Occur above specific dose threshold
    - › Severity increases with increased dose
- The most radiosensitive tissues are those with the highest mitotic activity, such as skin, bone marrow, thyroid, thymus, gonads, the lens of the eye and fetal tissue.
- The pertinent effects of radiation exposure during pregnancy include intrauterine growth retardation, teratogenesis and fetal death. The threshold dose for such effects, however, are high, at >20 Gy.
- Pregnant IRs employing appropriate safety precautions can safely perform IR procedures throughout the entire pregnancy with very low embryonic and fetal radiation exposure risk (approximately 30 mrem).

References

1 Goodman TR. Ionizing radiation effects and their risk to humans. Accessed 6/11/18 at Image Wisely®, the American College of Radiology, www.acr.org.

2 Dauer LT. et al. Occupational Radiation Protection of Pregnant or Potentially Pregnant Workers in IR: A Joint Guideline of the Society of Interventional Radiology and the Cardiovascular and Interventional Radiological Society of Europe. JVIR. 2015; 26(2):17 -181.

3 https://www.nrc.gov/reading-rm/doc-collections/cfr/part020/.

4 Marx MV, Niklason L, Mauger EA. Occupational radiation exposure to interventional radiologists: a prospective study. J Vasc Interv Radiol. 1992;3(4):597-606.

5 Chandra V et al. Monitoring of fetal radiation exposure during pregnancy. J Vasc Surg. 2013;58 (3);710-714.

Additional resources

Vu CT, Elder DH. Pregnancy and the working interventional radiologist. *Semin Intervent Radiol*. 2013;30(4):403-7

https://ehs.stanford.edu/manual/radiation-protection-guidance-hospital-staff/maximum-permissible-occupational-doses <https://ehs.stanford.edu/manual/radiation-protection-guidance-hospital-staff/maximum-permissible-occupational-doses>

http://rfs.sirweb.org/2016/12/11/pregnancy-in-the-life-of-an-interventional-radiologist-featuring-dr-sarah-white/ <http://rfs.sirweb.org/2016/12/11/pregnancy-in-the-life-of-an-interventional-radiologist-featuring-dr-sarah-white/>