

ACR Appropriateness Criteria® Radiation Dose Assessment Introduction

Many of the diagnostic imaging examinations described in the ACR Appropriateness Criteria® (AC) guidelines involve exposure of patients to ionizing radiation from radioactive materials or x-rays. Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, relative radiation levels (RRLs) have been included for most imaging examinations (see Table 1) [1,2]. The RRLs are based on effective dose, which is a radiation dose quantity used to **estimate population** total radiation risk associated with an imaging procedure. This quantity takes into account the sensitivity to radiation of different body organs and tissues [3]. It is expressed in units of millisieverts (mSv). It is important to note that since effective dose does not delineate differences in risk based on age and sex, it cannot accurately specify risk for an individual patient. However, effective dose does provide a way to approximately compare relative risk between different imaging examinations. All RRL assignments are based on reviews of current literature and the experience of medical physicists and radiologists [4-10]. In some examinations, dose estimates from published studies and/or practice experience vary significantly; in these cases, the reviewing committee conservatively assigned the RRL for the examination to the higher level. These assignments will be periodically reviewed and updated, as practice evolves and further information becomes available.

Table 1. Relative radiation level designations along with common example examinations for each classification

Relative Radiation Level*	Effective Dose Estimate Range	Example Examinations
None	0	Ultrasound, MRI
Minimal	<0.1 mSv	Chest radiographs, hand radiographs
Low	0.1-1 mSv	Pelvis radiographs, mammography
Medium	1-10 mSv	Abdomen CT, barium enema, nuclear medicine bone scan
High	10-100 mSv	Abdomen CT without and with contrast, whole body PET

*RRL assignments are not included for some examinations. These are designated as IP (in progress) or NS (not specified). The RRL assignments for the IP examinations will be available in future releases. The RRL assignments for the NS examinations cannot be made because the RRL depends on the region of the body exposed to ionizing radiation, and the body part will vary as a function of the clinical situation.

The primary risk associated with exposure to ionizing radiation is cancer. Based on the BEIR VII report, it is estimated that approximately 1 in 1,000 individuals will develop cancer from an exposure of 10 mSv. This risk level is relatively small in comparison to approximately 420 out of 1,000 individuals expected to develop cancer from all other causes combined [11]. Keep in mind that cancer, regardless of the etiologic process, has a latent period of 10-20 years. Further, it is important to remember that in addition to radiation exposure from imaging procedures, individuals are exposed to background radiation from natural sources, including radon, cosmic rays, soil, building materials, and food. The average annual amount of natural background radiation for someone living in the United States is approximately 3 mSv [12].

The RRL designations specified in these guidelines assume an average adult patient size (or applicable pediatric size) and that typical imaging equipment, radiographic techniques, and radiopharmaceutical dosage levels are used. Radiation levels vary substantially as a function of differences in patient size and local imaging practices [13]. A qualified medical physicist must be consulted for more accurate dose estimates in specific clinical situations.

In the current version of the AC, RRLs are not included for most image-guided interventional procedures, since the actual patient doses in these procedures vary as a function of a number of factors. These include patient factors, such as body habitus and age, and technical factors, such as type of imaging modality used for guidance, specific nature of the intervention, treatment modality used, and skill and experience of the operator. For example, biopsy of a lung nodule may be done with fluoroscopic or CT guidance. The CT may involve static imaging or CT fluoroscopy. The lesion may be peripheral, large, and readily accessible, or central, small and technically very challenging to reach. Similarly, if a patient is undergoing visceral angiography for the treatment of a gastrointestinal bleed, the procedure may be very brief if a precise bleeding site is readily identified and treated with embolization, or it may require a long period of fluoroscopy and many recorded angiographic runs due to unclear or confusing findings, or inability to easily cannulate a small suspect artery. For these reasons, the actual dose to a given patient for a given intervention may vary from none to high. As the RRLs and the AC are further refined with additional information, RRLs will be added to the interventional procedures.

Certain patient groups require special attention with regard to radiation exposure. Radiation-induced cancer mortality risk in children is 3 to 5 times higher than for adults [3]. Even though radiation levels required for imaging examinations of children are generally lower than those for adults due to their smaller size, it is particularly important to consider radiation exposure levels when selecting appropriate imaging examinations for children due to their significantly greater sensitivity to radiation

exposure. Conversely, for CT examinations, radiation doses may not be lower for small patients and children. Unless specific pediatric reduced radiographic techniques have been implemented by the facility, the radiation levels for small patients and children may exceed typical adult radiation levels. It is also important to note that as people age, their risk of radiation-induced cancer decreases. As a result, when compared to a 40-year-old, an 80-year-old is 3 to 4 times less likely to develop cancer from radiation exposure [12].

The developing conceptus is also particularly sensitive to radiation exposure, which may result in various adverse effects on the fetus, including mental retardation, organ malformations, and childhood cancer. Though the fetal dose from diagnostic x-ray procedures is generally below the threshold for increased risk of developmental damage, unintended fetal exposure should be avoided by establishing the pregnancy status of female patients of reproductive age prior to conducting any imaging procedure which involves direct exposure of the abdomen [14]. Radiological examinations outside the abdominal region in general result in only minimal fetal exposure and can be done safely. Before any imaging procedures involving ionizing radiation are performed on pregnant patients, however, the clinical necessity, possible alternatives that do not involve ionizing radiation, and all other risk factors should be carefully evaluated, and if the examination is undertaken, it should potentially be modified to minimize radiation dose.

Although the overall risk of cancer induction from a diagnostic imaging procedure involving ionizing radiation is small, it is not zero. Therefore, it is important to minimize patient radiation exposure and avoid ordering unnecessary examinations. When selecting an imaging procedure, the patient's previous imaging examinations should be considered. A patient with a history of examinations in the Medium or High RRL classification may prompt selection of a slightly less indicated study with a lower RRL or one that does not use ionizing radiation. Above all, any exposure that accompanies an imaging exam should be justified based on the benefit to the patient.

Frequently patients will ask physicians questions about the radiation exposure associated with imaging examinations and the risk of ionizing radiation in general. An easily-accessible resource that can be used for these discussions is the RadiologyInfo website (www.radiologyinfo.org). This website provides information to the public on radiologic procedures, including specific content on radiation exposure and safety. The material is provided by experts in the field of radiology from the ACR and the Radiological Society of North America.

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References

1. Royal College of Radiologists. Making the best use of a department of clinical radiology: guidelines for doctors. 5th ed. London: The Royal College of Radiologists; 2003.
2. Martin CJ. Effective dose: how should it be applied to medical exposures? *Br J Radiol* 2007; 80(956):639-647.
3. International Commission on Radiological Protection, 1990 Recommendations of the International Commission on Radiological Protection, ICRP Publication 60. *Ann ICRP* 1991;21:1-3.
4. Conference of Radiation Control Program Directors. Thirty years of NEXT: Available at: <http://www.crcpd.org/Pubs/NextTrifolds/ThirtyYearsOfNEXT.pdf>.
5. National Council on Radiation Protection and Measurements. Exposure of the US population from diagnostic medical radiation, NCRP Report No. 100. Bethesda, MD; 1989.
6. Conference of Radiation Control Program Directors. Nationwide Evaluation of X-Ray Trends (NEXT) - Tabulation and Graphical Summary of 2000 Survey of Computed Tomography: <http://www.fda.gov/cdrh/ct/2000survey.html>; 2007:In publication: CRCPD publication no. E-07-02.
7. *United States Pharmacopeia Drug Information: Drug Information for the Health Care Professional*. 27th ed. Greenwood Village, CO: Thomson Micromedex; 2007.
8. ICRP Publication 80: Radiation Dose to Patients from Radiopharmaceuticals. Rev ed: Elsevier; September 1, 1999.
9. Mettler FA, Jr., Huda W, Yoshizumi TT, Mahesh M. Effective doses in radiology and diagnostic nuclear medicine: a catalog. *Radiology* 2008; 248(1):254-263.
10. Wall BF, Hart D. Revised radiation doses for typical X-ray examinations. Report on a recent review of doses to patients from medical X-ray examinations in the UK by NRPB. National Radiological Protection Board. *Br J Radiol* 1997; 70(833):437-439.
11. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, National Research Council. Health risks from exposure to low levels of ionizing radiation: BEIR VII phase 2. Washington, DC: The National Academies Press; 2006.
12. National Council on Radiation Protection and Measurements. Ionizing radiation exposure of the population of the United States., NCRP Report No. 93. Bethesda, MD; 1987.
13. Amis ES, Jr., Butler PF, Applegate KE, et al. American College of Radiology white paper on radiation dose in medicine. *J Am Coll Radiol* 2007; 4(5):272-284.
14. ACR practice guideline for imaging pregnant or potentially pregnant adolescents and women with ionizing radiation. In: *Practice Guidelines and Technical Standards*. Reston, Va: American College of Radiology; 2008:23-37.