

ACR Appropriateness Criteria® Radiation Dose Assessment Introduction

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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 radiographs. It is important to be aware of potential health risks associated with radiation exposure 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 a qualitative rating system for effective dose ranges. Effective dose is a quantity that accounts for the sensitivity to radiation of different body organs and tissues [3]. Effective dose is expressed in units of millisievert (mSv). It is important to note that, because 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 estimate risk among different imaging examinations. All RRL assignments are based on reviews of current literature, United States diagnostic reference level publications, and the experience of medical physicists and radiologists. A partial list of literature consulted is provided [4-20]. 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, equipment becomes more capable of dose savings, and further information becomes available.

The primary risk associated with exposure to ionizing radiation in medical imaging is potential induction of cancer. The National Academies' Health Risks from Exposure to Low Levels of Ionizing Radiation report, BEIR VII [21], states:

On average, assuming a sex and age distribution similar to that of the entire U.S. population, the BEIR VII lifetime risk model predicts that approximately one individual in 100 persons would be expected to develop cancer (solid cancer or leukemia) from a dose of 100 mSv while approximately 42 of the 100 individuals would be expected to develop solid cancer or leukemia from other causes. Lower doses would produce proportionally lower risks.

BEIR VII also emphasizes that:

At doses of 100 mSv or less, statistical limitations make it difficult to evaluate cancer risk in humans.

Adverse health outcomes for radiation doses below 100 mSv are not shown by evidence and the American Association of Physicists in Medicine (AAPM) cautions that [22]:

Given the lack of scientific consensus about potential risks from low doses of radiation, predictions of hypothetical cancer incidence and mortality from the use of diagnostic imaging are highly speculative. The AAPM and other radiation protection organizations specifically discourages these predictions of hypothetical harm. Such predictions can lead to sensationalistic stories in the public media. This may lead some patients to fear or refuse safe and appropriate medical imaging, to the detriment of the patient.

Keep in mind that cancer, regardless of the etiologic process, has a minimum latent period of years to decades [23,24]. Further, it is important to remember that in addition to radiation exposure from imaging procedures, individuals are exposed to ubiquitous 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 [7].

The RRL designations in these documents are general population-based ranges to allow relative comparisons between different procedures and are not meant to precisely predict radiation dose for individual patient examination

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scenarios. Radiation levels vary substantially as a function of differences in equipment, protocols, and patient factors [25]. For procedures where a more general description is provided (eg, CT appendicular skeleton), dose will vary depending on the area being imaged. 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 designated as “varies” for some image-guided interventional procedures, because 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 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. In addition, breast biopsy may be guided on an x-ray mammography unit or with no ionizing radiation using ultrasound or MRI. For these reasons, the actual dose to a given patient for a given intervention may vary from none to high.

Certain patient groups require special attention with regard to quantifying radiation exposure including more careful consideration of modalities that do not use ionizing radiation. In general, radiation-induced cancer mortality risk in children is 3 to 5 times higher than for adults [3], both because of increased organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults. 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 greater sensitivity to radiation exposure [26,27]. However, in practice, radiation doses may not be lower for small patients and children. If the radiation exposure from a protocol designed for an adult is used for smaller body sizes, the dose is larger. Unless specific pediatric-reduced techniques have been implemented by the facility, the radiation levels for small patients and children may exceed typical adult radiation levels [28]. 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 [21].

The developing fetus is sensitive to radiation exposure. Depending on the magnitude of the radiation dose and the gestational age of the fetus, these effects may include childhood cancer [29]. Though the fetal dose from diagnostic x-ray procedures is generally well below the threshold for increased risk of developmental or physical 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 [30]. In addition, caution should be used with some radiopharmaceuticals. Radiological examinations outside the abdominal and pelvic regions in general result in only minimal fetal exposure and most often can be performed 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.

Although the overall risk of cancer induction from a diagnostic imaging procedure involving ionizing radiation is small, it has not been proven to be zero. Therefore, it is prudent to ensure that a patient’s radiation exposure is only that necessary to accomplish the diagnostic task. There are several strategies to help accomplish the goal of limiting exposure to ionizing radiation. Use of appropriateness criteria recommendations to select the most suitable procedure for the patient’s condition; avoid ordering procedures that are not likely to provide useful information. Prior to ordering an imaging procedure, review the patient’s history, results, and clinical indications to determine whether the procedure can provide additional information to assist in patient management. Consider using imaging procedures that do not use ionizing radiation, but only if they have similar diagnostic accuracy to procedures that use ionizing radiation [31].

Frequently, patients will ask a physician 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. Additional information on radiation in imaging is available for imaging professionals, referring practitioners and patients and their families at the Image Wisely® (www.imagewisely.org/) and the Image Gently® (www.imagegently.org/) websites.

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

Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range	Example Examinations
○	0 mSv	0 mSv	Ultrasound; MRI
☼	<0.1 mSv	<0.03 mSv	Chest radiographs; Hand radiographs
☼☼	0.1-1 mSv	0.03-0.3 mSv	Pelvis radiographs; Mammography
☼☼☼	1-10 mSv	0.3-3 mSv	Abdomen CT with IV contrast, Nuclear medicine bone scan
☼☼☼☼	10-30 mSv	3-10 mSv	Abdomen CT without and with contrast; Whole body PET/CT
☼☼☼☼☼	30-100 mSv	10-30 mSv	CTA chest abdomen and pelvis with contrast; Transjugular intrahepatic portosystemic shunt placement

*The RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, the region of the body exposed to ionizing radiation, the imaging guidance that is used, etc.). The RRLs for these examinations are designated as “Varies.”

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