

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.

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 designated as NS (not specified) 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.

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], 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 significantly greater sensitivity to radiation exposure [14]. 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

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procedure which involves direct exposure of the abdomen [15]. 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 reduce 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 reduce patient radiation exposure to as great an extent as possible. There are several ways to help accomplish the goal of limiting exposure to ionizing radiation so as to maximize the risk-benefit ratio of imaging procedures. First, use the appropriateness criteria ratings to select the most suitable procedure for the patient's condition; avoid ordering procedures that are not likely to provide useful information. Second, prior to ordering new imaging procedures, review the patient's imaging history to determine if new imaging is truly likely to add necessary

information. Third, be mindful of the total radiation exposure to each patient, from past, current and possible future imaging with ionizing radiation, to ensure the radiation risk is justified based on the possible benefit to the individual.

Frequently patients will ask physician's 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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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
O	0	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, nuclear medicine bone scan
⊕⊕⊕⊕	10-30 mSv	3-10 mSv	Abdomen CT without and with contrast, whole body PET
⊕⊕⊕⊕⊕	30-100 mSv	10-30 mSv	Transjugular intrahepatic portosystemic shunt placement, Aortic aneurysm stent graft treatment

*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 NS (not specified).

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