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The American College of Radiology will periodically define new practice guidelines and technical standards for radiologic practice to help advance the science of radiology and to improve the quality of service to patients throughout the United States. Existing practice guidelines and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice guideline and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review, requiring the approval of the Commission on Quality and Safety as well as the ACR Board of Chancellors, the ACR Council Steering Committee, and the ACR Council. The practice guidelines and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice guideline and technical standard by those entities not providing these services is not authorized.

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ACR PRACTICE GUIDELINE FOR DIAGNOSTIC REFERENCE LEVELS IN MEDICAL X-RAY IMAGING

PREAMBLE

These guidelines are an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. They are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care. For these reasons and those set forth below, the American College of Radiology cautions against the use of these guidelines in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the physician or medical physicist in light of all the circumstances presented. Thus, an approach that differs from the guidelines, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in the guidelines when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of the guidelines. However, a practitioner who employs an approach substantially different from these guidelines is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment.

Therefore, it should be recognized that adherence to these guidelines will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of these guidelines is to assist practitioners in achieving this objective.

I. INTRODUCTION

This guideline has been revised by the American College of Radiology (ACR) to guide appropriately trained and licensed physicians and medical physicists involved in diagnostic procedures using ionizing radiation. The establishment of reference levels in diagnostic medical imaging requires close cooperation and communication between the physicians who are responsible for the clinical management of the patient and the medical physicist responsible for monitoring equipment and image quality and estimating patient dose. Adherence to this guideline should help to maximize the efficacious use of these procedures, minimize radiation dose to patients and staff, maintain safe conditions, and ensure compliance with applicable regulations.

Application of this guideline should be in accordance with the specific ACR guidelines or standards for the relevant imaging modality; considerations of image quality monitoring; radiation safety; and the radiation protection of patients, personnel, and the public. There must also be compliance with applicable laws and regulations.

II. DEFINITION

The term diagnostic reference level or reference value sets an investigation level to identify unusually high radiation doses or exposure levels for common diagnostic medical X-ray imaging procedures [1-3].

Reference levels are based on actual patient doses for specific procedures measured at a number of representative clinical facilities. The levels are set at approximately the 75th percentile of these measured data, meaning that the procedures are performed at most institutions with doses at or below the reference level. Consequently, reference levels are suggested action levels at which a facility should review its methods and determine if acceptable image quality can be achieved at lower doses.

III. GOAL

The goal of this guideline is to provide guidance and advice to physicians and medical physicists on the establishment and implementation of reference levels in the practice of diagnostic medical X-ray imaging. The goal in medical imaging is to obtain image quality consistent with the medical imaging task. Diagnostic reference levels are used to manage the radiation dose to the patient. The medical radiation exposure must be controlled, avoiding unnecessary radiation that does not contribute to the clinical objective of the procedure. By the same token, a dose significantly lower than the reference level may also be cause for concern, since it may indicate that adequate image quality is not being achieved. The specific purpose of the reference level is to provide a benchmark for comparison, not to define a maximum or minimum exposure limit.

IV. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

A. Physician

Procedures using radiation for diagnostic medical purposes must be performed under the supervision of, and interpreted by, a licensed physician with the following qualifications:

1. Certification in Radiology or Diagnostic Radiology by the American Board of Radiology, the American Osteopathic Board of Radiology, the Royal College of Physicians and Surgeons of Canada, or Le College des Medecins du Quebec.
or
2. Completion of an Accreditation Council for Graduate Medical Education (ACGME) approved residency program or an American Osteopathic Association (AOA) approved residency program and shall have documented a

minimum of 6 months of formal dedicated training in the interpretation and formal reporting of general radiographs and fluoroscopy for patients of all ages that includes radiographic training on all body areas. For computed tomography (CT) the physician shall have documented involvement with the performance, interpretation, and reporting of 500 CT examinations in the past 36 months.

and

3. The physician should have documented training in and understanding of the physics of diagnostic radiography (including fluoroscopy and CT) and experience with the equipment needed to safely produce the images. This should include general radiography, screen-film combinations, conventional image processing, and digital image processing.

The physician is the principal individual involved in establishing and implementing reference levels in diagnostic medical imaging using ionizing radiation. The physician should work closely with a Qualified Medical Physicist in this process. The clinical objectives of all diagnostic medical imaging procedures must be in accordance with current ACR guidelines or standards and should be periodically reviewed by the physician.

Continuing Medical Education

The physician's continuing medical education should be in accordance with the [ACR Practice Guideline for Continuing Medical Education \(CME\)](#) and should include CME in general radiography as is appropriate to his/her practice.

B. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently one or more of the subfields in medical physics. The ACR considers certification and continuing education and experience in the appropriate subfield(s) to demonstrate that an individual is competent to practice one or more of the subfields in medical physics and to be a Qualified Medical Physicist. The ACR recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physics in Medicine, or for MRI, by the American Board of Medical Physics (ABMP) in magnetic resonance imaging physics.

The appropriate subfields of medical physics for this guideline are Diagnostic Radiological Physics or Radiological Physics.

A Qualified Medical Physicist should meet the [ACR Practice Guideline for Continuing Medical Education](#)

(CME). (ACR Resolution 17, 1996 – revised in 2008, Resolution 7)

CME should include education in radiation dosimetry, radiation protection, and equipment performance related to the use of medical imaging.

Regular performance of radiation measurements, dosimetric calculations, and performance evaluation of equipment in use in sufficient numbers to maintain competence is essential.

The medical physicist must be familiar with the principles of imaging physics, radiation dosimetry, and radiation protection; the current guidelines of the National Council on Radiation Protection and Measurements; laws and regulations pertaining to the performance and operation of medical X-ray imaging equipment; the function, clinical uses, and performance specifications of the imaging equipment; and calibration processes and limitations of the instruments used for radiation measurement. The medical physicist must also be familiar with relevant clinical procedures.

V. DIAGNOSTIC REFERENCE LEVELS FOR IMAGING WITH IONIZING RADIATION

This guideline recommends reference levels and suggests the methods of measurement for comparison for procedures in radiography, fluoroscopy, and CT.

A. Radiography

For radiography, including screen-film and digital imaging, this guideline bases reference levels on a measurement of entrance skin exposure (without backscatter) to a standard phantom using the X-ray technique factors the facility would typically select for an average size adult patient. Reference levels are provided for 2 common imaging tasks: a posteroanterior (PA) chest radiograph and an anteroposterior (AP) abdomen (e.g., KUB) radiograph. The standard phantoms recommended are the chest and abdomen phantoms developed for the ACR Radiography/Fluoroscopy Accreditation Program or equivalent phantoms. These phantoms consists of several 25.4 by 25.4 cm acrylic blocks (Plexiglas, polymethyl methacrylate [PMMA], or Perspex) and a type 1100 aluminum plate that combine to form chest and abdomen equivalent phantoms [4]. These phantoms are similar in composition to phantoms developed by the Center for Devices and Radiological Health (CDRH) for the National Evaluation of X-ray Trends (NEXT) surveys [5-7]. Dose estimates obtained using these phantoms may differ somewhat from those obtained using the NEXT phantoms.

The chest phantom is made from a 7.6 cm thickness of acrylic and a 4.6 mm thickness of aluminum (on the beam entrance side of the phantom) with a 7.7 cm air gap between the exit plane of the phantom and the entrance plane of the image receptor assembly. The abdomen phantom consists of a 19.3 cm thickness of acrylic and 4.6 mm thickness of aluminum (on the beam entrance side of the phantom). For dosimetry purposes, the abdomen phantom is equivalent to 23 cm of water or 22 cm of acrylic. The chest phantom (with air gap) is equivalent to 10.5 cm water or 10 cm of acrylic. The aforementioned equivalence of acrylic or water may be used in lieu of the ACR accreditation phantom.

For radiographic entrance skin exposure measurement, the chest or abdomen phantom is centered in the field of view with beam collimation adjusted to the phantom edges. An exposure is made using the automatic exposure control settings or manual technique routinely used clinically for the appropriate patient thickness. The technique chosen for the exposure (kVp, mA, and time if not exposed under automatic exposure controlled conditions) should be the same as that used clinically for an AP abdomen radiograph or PA chest radiograph for an average size adult patient. The entrance skin exposure may be either measured directly or calculated from a free-in-air output (mR/mAs) measurement with appropriate inverse square correction to the actual phantom entrance surface. See AAPM Report No. 31 for further instructions on exposure measurement techniques [8]. For a PA chest radiograph, the reference level is 25 mR (0.22 mGy air kerma). For an AP abdomen radiograph, the reference level is 600 mR (5.3 mGy air kerma).

B. Fluoroscopy

A reference level is provided for abdominal fluoroscopy. The abdomen phantom described in Section V.A is configured with a 10 cm air gap between the entrance plane of the phantom and the table for undertable X-ray tube configurations with the aluminum plate facing the X-ray tube. For overtable X-ray tube fluoroscopy, the abdomen phantom is placed directly on the table with the aluminum plate toward the X-ray tube [4,9].

Reference levels for fluoroscopic entrance skin exposure rate are based on the use of an image intensifier field of view of 23 cm. Exposure rates are measured with the abdomen phantom centered in the field of view, with beam collimation to a width of 14 cm on the beam exit side of the phantom. For undertable X-ray tube systems, position an ion chamber under the phantom so that the chamber volume is centered 1 cm above the tabletop. For overtable X-ray tube systems, position the ion chamber 30 cm above the tabletop using an external probe support stand. Center the ion chamber under fluoroscopic guidance. Using the same fluoroscopic imaging settings

that would be used for a double-contrast barium enema examination, allow exposure rate readout to stabilize, and record the exposure rate. The reference level is 6.5 R/min (57 mGy/min air kerma). Note that this value reflects the ion chamber reading at the specified location (1 cm above the table top for undertable X-ray tube systems and 30 cm above the table top for overtable X-ray tube systems) and is not corrected to the actual phantom entrance surface, as are the radiographic reference levels.

The reference levels below were derived from the results of the NEXT survey [5].

Examination	Reference Levels
PA chest	25 mR (0.22 mGy air kerma)
AP abdomen	600 mR (5.3 mGy air kerma)
Abdominal fluoroscopy	6.5 R/min (57 mGy/min air kerma)

C. Computed Tomography

For CT, the diagnostic reference levels are based on the volume CT dose index (CTDI_{vol}). The CTDI_{vol} is derived from the peripheral and axial CTDI₁₀₀. Additionally, CTDI_{vol} takes into account gaps or overlaps between the radiation beams from contiguous rotations of the X-ray source. The CTDI₁₀₀ is determined using a special 10 cm long pencil ionization chamber. The CTDI value is the exposure from a single axial scan (integral of the radiation beam profile measured by the long chamber) divided by the total nominal beam width nT, where T is the width of each active channel, and n is the number of active channels. Thus, $CTDI_{100} = f \cdot C \cdot D \cdot L / nT$, where f is the exposure to dose (air kerma) conversion factor (8.76 mGy/Roentgen), C is the chamber calibration coefficient (R/reading), D is the reading, and L is the active length of the chamber. The CTDI₁₀₀ approximates the multiple slice average dose (MSAD) for a series of scanner rotations [10-12].

The International Electrotechnical Commission (IEC) has specifically defined the CTDI₁₀₀, weighted CTDI_w, and CTDI_{vol} [13]. The standard 16 cm diameter (head/pediatric body) or 32 cm diameter (body) acrylic phantoms have cylindrical holes drilled at the center and several peripheral positions to allow for insertion of the pencil ionization chamber. The CTDI_w is obtained by adding two-thirds of the CTDI₁₀₀ peripheral dose with one-third of the CTDI₁₀₀ center dose ($CTDI_w = (2/3) CTDI_{100} \text{ peripheral} + (1/3) CTDI_{100} \text{ center}$). CTDI_{vol} is obtained by dividing CTDI_w by the pitch value, where pitch is defined for either axial or helical scanning as the ratio of table travel per rotation (I) to the total nominal beam width (n·T). Thus, $CTDI_{vol} = CTDI_w / \text{pitch} = CTDI_w / nT / I$. The 16 cm diameter phantom must be used for the CT head and CT pediatric abdomen examinations

and the 32 cm diameter phantom must be used for CT adult abdomen examinations.

The recommended diagnostic CT reference levels below were derived from analysis of the data gathered from the first 3 years of the ACR CT Accreditation Program.

Examination	Reference Levels (CTDI _{vol})
CT head	75 mGy
CT adult abdomen	25 mGy
CT pediatric abdomen (5 years old)	20 mGy

VI. PATIENT SPECIFIC DOSIMETRY

Because the reference levels are derived from standard phantom measurements and are used as benchmarks for comparison of X-ray dose estimates from a given facility, they should not be used as a substitute for estimating specific doses delivered to a patient. On occasion the need may arise to estimate the dose delivered to a patient because of a specific situation (e.g., pregnancy, prolonged fluoroscopy, multiple examinations). In these situations it is recommended that the physician consider executing a formal written medical physics consultation with the medical physicist. Using the specific X-ray parameters of the diagnostic examination, the medical physicist can render an estimate of the specific dose to a given location in the patient, such as the location of the embryo/fetus or the patient's skin. The consultation request and the medical physicist's report should be duly signed by the requesting physician and the medical physicist and should be incorporated into the patient's medical record.

VII. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, radiologic technologists, and all supervising physicians have a responsibility to minimize radiation dose to individual patients, to staff, and to society as a whole, while maintaining the necessary diagnostic image quality. This concept is known as "as low as reasonably achievable (ALARA)."

Facilities, in consultation with the medical physicist, should have in place and should adhere to policies and procedures, in accordance with ALARA, to vary examination protocols to take into account patient body habitus, such as height and/or weight, body mass index or lateral width. The dose reduction devices that are available on imaging equipment should be active; if not, manual techniques should be used to moderate the exposure while maintaining the necessary diagnostic image quality. Periodically, radiation exposures should be measured and patient radiation doses estimated by a medical physicist in accordance with the appropriate ACR Technical Standard. (ACR Resolution 17, adopted in 2006 – revised in 2009, Resolution 11)

VIII. QUALITY CONTROL AND IMPROVEMENT, SAFETY, INFECTION CONTROL, AND PATIENT EDUCATION

A. Policies and Procedures

Policies and procedures related to quality, patient education, infection control, and safety should be developed and implemented in accordance with the ACR Policy on Quality Control and Improvement, Safety, Infection Control, and Patient Education Concerns appearing elsewhere in the ACR Practice Guidelines and Technical Standards book.

B. Equipment Performance Monitoring

Equipment performance monitoring should be in accordance with the appropriate ACR Technical Standard.

C. Follow-Up Procedures and Written Survey Reports

The medical physicist shall report the findings to the physician(s), the responsible professional(s) in charge of obtaining or providing service to the equipment and, in the case of the consulting physicist(s), to the representative of the hiring party, and, if appropriate, initiate the required service. Action shall be taken immediately by verbal communication if there is imminent danger to patients or staff using the equipment due to unsafe conditions. Written survey reports shall be provided in a timely manner consistent with the importance of any adverse findings.

Results that exceed the established reference levels must be investigated to the satisfaction of the medical physicist and the physician involved.

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Suggested Additional Reading

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