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The American College of Radiology will periodically define new practice parameters 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 parameters and technical standards will be reviewed for revision or renewal, as appropriate, on their fifth anniversary or sooner, if indicated.

Each practice parameter 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 and approval. The practice parameters 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 parameter and technical standard by those entities not providing these services is not authorized.

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ACR–AAPM–SPR PRACTICE PARAMETER FOR DIAGNOSTIC REFERENCE LEVELS AND ACHIEVABLE DOSES IN MEDICAL X-RAY IMAGING

PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care¹. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents 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 practice parameters, 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 practice parameters 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 practice parameters. However, a practitioner who employs an approach substantially different from these practice parameters 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 practice parameters 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 practice parameters is to assist practitioners in achieving this objective.

¹ *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing*, ___ N.W.2d ___ (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, *Stanley v. McCarver*, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.

I. INTRODUCTION

This practice parameter has been revised collaboratively by the American College of Radiology (ACR), the American Association of Physicists in Medicine (AAPM), and the Society for Pediatric Radiology (SPR) to guide appropriately trained and licensed physicians and Qualified 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 team of physicians who are responsible for the clinical management of the patient, the Qualified Medical Physicist who is responsible for monitoring equipment and image quality and estimating patient dose, and the radiologic technologist who is responsible for adherence to protocols. Adherence to this practice parameter should help maximize the efficacy of these procedures, optimize patient radiation dose and image quality, minimize radiation dose to staff, maintain safe conditions, and ensure compliance with applicable regulations. This is particularly important for children who are more vulnerable than adults to the potential risks of ionizing radiation.

Application of this practice parameter should be in accordance with the specific ACR practice parameters or technical standards for the relevant imaging modality. Considerations should also be made for 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.

This practice parameter summarizes existing national diagnostic reference levels (DRLs) and achievable doses (ADs) and provides guidance and advice to physicians and Qualified Medical Physicists on the implementation of these 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. DRLs and ADs are used to help manage radiation dose to the patient. Medical radiation dose must be controlled, avoiding unnecessary radiation that does not contribute to the clinical objective of the procedure. Extremely low doses may also be a cause for concern because they may indicate that adequate image quality is not being achieved. The specific purpose of DRLs and ADs is to provide benchmarks for comparison, not to define maximum or minimum dose limits.

II. DEFINITION

A DRL is an investigational level used to identify unusually high radiation doses for common diagnostic medical X-ray imaging procedures [1-9]. DRLs are suggested action levels above which a facility should review its methods and determine if acceptable image quality can be achieved at lower doses. The International Commission on Radiological Protection (ICRP) emphasizes that DRLs “are not for regulatory or commercial purposes, not a dose restraint and not linked to limits or constraints.”

DRLs are based on standard phantom or patient measurements under specific conditions at a number of representative clinical facilities. DRLs have been set at approximately the 75th percentile of measured patient or phantom data. This means that procedures performed at 75% of the institutions surveyed have exposure levels at or below the DRL. The ICRP also emphasizes that DRLs should not be applied to individual patients [9]. To make meaningful comparisons, aggregate facility data collected in the same manner that the benchmark DRLs were developed should be compared against the DRL.

ADs can be used with DRLs to assist in optimizing image quality and dose. ADs are set at approximately the median (50th percentile) of the study dose distribution, ie, half of the facilities are producing images at lower doses and half are using higher doses. Further information on ADs is available in the National Council on Radiation Protection and Measurements (NCRP) Report 172 [4].

The United Kingdom’s Public Health England, formerly known as the National Radiological Protection Board and then the Health Protection Agency, reported that the 2005 DRLs for radiography, fluoroscopy, and dental X-rays were approximately 16% lower than those in 2000 and were approximately half of those in the mid-1980s [10].

It is important to note that too low of a radiation dose may result in inadequate image quality for the diagnostic task. However, the references used to develop DRLs and ADs for this practice parameter did not provide

corresponding quantitative assessments of image quality. This limits the development of dose benchmarks below which image quality would be unacceptable. Lower level dose benchmark development is also challenged by ongoing improvements in X-ray beam production (eg, adaptive beam filtration, slot-scanning), image receptor technology (ie, higher detective quantum efficiency radiation detectors), and image reconstruction algorithms (ie, iterative reconstruction) that may result in acceptable image quality at radiation doses substantially lower than the ADs referenced in this practice parameter. Consequently, lower level dose investigation benchmarks are not provided in this document. Facilities with patient doses significantly below the ADs presented in this practice parameter (who have not evaluated and implemented specific dose-reduction protocols) should conduct a review of clinical image quality to determine whether these low-dose examinations are resulting in poor image quality that may be detrimental to patient care [4].

DRLs and ADs are part of the optimization process. It is essential to ensure that image quality appropriate for the diagnostic purpose is achieved when changing patient doses. Optimization must balance image quality and patient dose, ie, image quality must be maintained at an appropriate level as radiation doses are decreased.

III. 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 the Collège des Médecins du Québec.

or

2. Completion of a residency program approved by the Accreditation Council for Graduate Medical Education), the American Osteopathic Association, the Royal College of Physicians and Surgeons of Canada, or the Collège des Médecins du Québec, and have documented a minimum of 6 months of formal dedicated training in the interpretation and formal reporting of radiographic images and fluoroscopy for patients of all ages that includes training on all body areas. For fluoroscopy, the physician should meet the personnel qualifications outlined in the [ACR–AAPM Technical Standard for Management of the Use of Radiation in Fluoroscopy Procedures](#) [11]. For computed tomography (CT), the physician should meet the personnel qualifications outlined in the [ACR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography \(CT\)](#) [12].

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 generation of the X-ray beam, image receptor technology, and 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 practice parameters or technical 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 Parameter for Continuing Medical Education \(CME\)](#) and should include CME in general radiography as is appropriate to their practice [13].

B. Qualified Medical Physicist

A Qualified Medical Physicist is an individual who is competent to practice independently in one or more of the subfields in medical physics. The American College of Radiology (ACR) considers certification, 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 strongly recommends that the individual be certified in the appropriate subfield(s) by the American Board of Radiology (ABR), the Canadian College of Physicists in Medicine, or the American Board of Medical Physics (ABMP).

A Qualified Medical Physicist should meet the [ACR Practice Parameter for Continuing Medical Education \(CME\)](#). (ACR Resolution 17, adopted in 1996 – revised in 2012, Resolution 42) [13]

The appropriate subfield of medical physics for this practice parameter is Diagnostic Medical Physics (including medical physics certification categories of Radiological Physics, Diagnostic Radiological Physics, or Diagnostic Imaging Physics.)

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 is essential to maintain competence.

The Qualified Medical Physicist must be familiar with the principles of imaging physics, radiation dosimetry, and radiation protection; the current guidelines of the NCRP; 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 Qualified Medical Physicist must also be familiar with relevant clinical procedures.

IV. DIAGNOSTIC REFERENCE LEVELS AND ACHIEVABLE DOSES FOR X-RAY IMAGING

This practice parameter provides DRLs and ADs for procedures in radiography, noninterventional fluoroscopy, and CT. As explained in the NCRP Report 172, national DRL and AD levels have undergone significant reductions since the Nationwide Evaluation of X-Ray Trends (NEXT) data were first acquired and published. Radiology practice, equipment, and radiation dose levels have continued to improve since the last publication of NEXT data. Most radiology departments have converted from screen-film to computed radiography and digital radiography. In fluoroscopy, many institutions have converted to flat panel detectors with a wider range of operating modes and beam filtrations. Many of the DRLs and ADs in this practice parameter are based on the most current NEXT studies as this is the only nationwide survey data from the United States currently available. However, the data in many of these studies are well over 10 years old. Other sources of more current dose information may be available from geographically localized studies (eg, the state of Michigan) [14].

Modern facilities may be able to achieve acceptable image quality at doses that are even lower than the national DRLs and ADs provided in this practice parameter. A Qualified Medical Physicist should be consulted to assist in determining if lower doses are possible based on an institution's current technology and clinical practice.

A. Radiography

For radiography, including digital imaging and screen-film, this practice parameter bases DRLs and ADs on a measurement of air kerma at the entrance skin plane (without backscatter) to a standard phantom using the X-ray image acquisition parameters the facility would typically select for an average-sized adult or pediatric patient. DRLs are provided for five radiographic projections (Table 1).

The phantoms and details of measurements are provided in NCRP Report 172 and the appropriate NEXT reports [4,15]. The sizes of the adult and pediatric patients modeled by the phantoms are given in Table 1. The adult chest DRLs and ADs are based on NEXT data collected in 2001; the pediatric chest DRLs and ADs are based on NEXT

data collected in 1998; and the adult abdomen and lumbosacral spine DRLs and ADS are based on NEXT data collected in 2002. For more current data from a geographically-localized study, see the state of Michigan website [14].

Table 1
DRLs and ADs for Adult and Pediatric X-Ray Examinations (incident air kerma, free-in-air)

Examination (patient thickness)	DRL (mGy)	AD (mGy)
Adult PA chest (23 cm), with grid	0.15	0.11
Pediatric PA chest (12.5 cm), with grid	0.12	0.07
Pediatric PA chest (12.5 cm), without grid	0.06	0.04
Examination (patient thickness)	DRL (mGy)	AD (mGy)
Adult AP abdomen (22 cm)	3.4	2.4
Adult AP lumbosacral spine (22 cm)	4.2	2.8

B. Fluoroscopy

DRLs and ADs are provided for abdominal fluoroscopy in Table 2. For fluoroscopy, this practice parameter bases DRLs and ADs on a measurement of incident air kerma (with some backscatter due to geometry) to a standard phantom using the image acquisition parameters the facility would typically select for a 22-cm adult PA abdomen (referenced to a location 1 cm above the patient support surface for conventional systems with the X-ray source beneath the patient support) [4]. Published reference levels are currently not available for pediatric patients.

The phantoms and details of measurements are provided in NCRP Report 172 and the appropriate NEXT Reports [4,15]. In Table 2, a 22-cm PA abdomen was modeled by phantom measurements with a grid. The adult abdomen fluoroscopic DRLs and ADs are based on NEXT data collected in 2003.

Table 2
DRLs and ADs for Under Table Adult (22-cm PA Abdomen) Fluoroscopic Imaging (incident air kerma rate, with backscatter)

Phantom: Adult PA Abdomen with grid	DRL	AD
Upper GI fluoroscopy, without oral contrast media	54 mGy min ⁻¹	40 mGy min ⁻¹
Upper GI fluoroscopy, with oral contrast media	80 mGy min ⁻¹	72 mGy min ⁻¹
Fluorographic image, without contrast (incident air kerma, with backscatter)		
Film	3.9 mGy	2.5 mGy
Digital	1.5 mGy	0.9 mGy
Fluorographic image, with contrast (incident air kerma, with backscatter)		
Film	27.5 mGy	18.7 mGy
Digital	9.9 mGy	5.3 mGy

C. Computed Tomography

Two sets of DRLs and ADs are provided for adult CT, one developed from phantom data and the second from actual patient data. Because US DRLs have traditionally been based on phantom data and the national collection and analysis of patient data is relatively new, both are included.

The DRLs and ADs for CT developed from phantom data are based on the volume CT dose index ($CTDI_{vol}$). The International Electrotechnical Commission has specifically defined the $CTDI_{100}$, weighted $CTDI_w$, and $CTDI_{vol}$ [16]. For the values reported in Table 3, a 16-cm-diameter polymethyl methacrylate cylinder phantom was used for all head CT examinations and a 32-cm-diameter phantom was used for all adult body CT examinations. Both 16- and 32-cm phantom DRLs and ADs are provided for pediatric abdomen examinations.

The phantom-based CT DRLs were derived from analysis of the data gathered from the first 3 years of the ACR CT Accreditation Program [17,18], from evaluation of more current CT Accreditation Program data [19], 2005 CT NEXT data, and NCRP Report 172. The lateral dimensions are for average-sized patients of the specified age [20].

Table 3
Phantom-Based DRLs and ADs for Adult and Pediatric CT ($CTDI_{vol}$)

Examination	Patient Lateral Dimension (cm)	CTDI Phantom Diameter (cm)	$CTDI_{vol}$	
			DRL (mGy)	AD (mGy)
Adult head [4,17]	16	16	75	57
Adult abdomen-pelvis [4,17]	38	32	25	17
Adult chest [4]	35	32	21	14
Pediatric 1-year-old head [19]	15	16	35	*
Pediatric 5-year-old abdomen-pelvis [19]	20	16	15	*
		32	7.5	*

**ADs are not available for pediatric studies from source reference [19]*

Table 4 presents patient-based adult CT DRLs and ADs presented as $CTDI_{vol}$, size-specific dose estimates (SSDE) [21], and dose length products (DLP) [22]. These benchmarks are the result of an analysis of the top 10 adult CT examinations submitted to the ACR's Dose Index Registry [23]. These examinations included 1.3 million examinations performed at 583 facilities in 2014 [24]. The DRLs and ADs are presented for the median patient sizes determined from localizer images [25,26] submitted with the dose parameters for each examination. (A broader range of size-specific DRLs and ADs are available in the source reference [24].) The patient size information is presented as lateral thickness for the head and brain studies and water-equivalent diameter [27] for all other examinations. (Because SSDE conversion factors for head and neck examinations are not available at this time, they are not included in the table.)

Table 4
Patient-Based DRLs and ADs for Adult CT [24]

Examination	Patient Size (cm)	CTDI _{vol} (mGy)		SSDE (mGy)		DLP (mGy-cm)	
		DRL	AD	DRL	AD	DRL	AD
Head and brain without contrast	14 to 16 (lat thickness)	56	49			962	811
Neck with contrast	18 to 22 (water-eq dia)	19	15			563	429
Cervical spine without contrast	18 to 22 (water-eq dia)	28	20			562	421
Chest without contrast	29 to 33 (water-eq dia)	12	9	15	11	443	334
Chest with contrast	29 to 33 (water-eq dia)	13	10	15	11	469	353
Chest pulmonary arteries with contrast	29 to 33 (water-eq dia)	14	11	17	13	445	357
Abdomen and pelvis without contrast	29 to 33 (water-eq dia)	16	13	19	15	781	639
Abdomen and pelvis with contrast	29 to 33 (water-eq dia)	15	12	18	15	755	608
Abdomen, pelvis, and kidney without contrast	29 to 33 (water-eq dia)	15	12	19	14	705	576
Chest, abdomen, and pelvis with contrast material	29 to 33 (water-eq dia)	15	12	18	14	947	779

Patient-based pediatric DRLs and ADs are available from two US publications. The study by Strauss et al [28] analyzed CT dose information from chest examinations performed on 518 pediatric patients at 5 hospitals in 2012 and 2013. The study by Goske et al [29] analyzed CT dose information from abdominal examinations performed on 939 pediatric patients at 6 hospitals in 2009. The DRLs and ADs, grouped by patient size, are summarized in Table 5.

Table 5
Patient-Based DRLs and ADs for Pediatric CT

Examination	Effective Diameter (cm)	Lateral Body Width (cm)	CTDI _{vol} (mGy)		SSDE (mGy)		DLP (mGy-cm)	
			DRL	AD	DRL	AD	DRL	AD
Chest [28]	<15	<18	1.8		3.9	2.1	28	
	15 to 19	18 to 23	2.0		4.5	3.0	52	
	20 to 24	24 to 30	3.2		5.1	3.4	80	
	25 to 29	31 to 35	4.8		6.6	4.7	148	
	≥30	...	7.8		8.4	6.3	253	
Abdomen [29]		<15	5.0	3.4	12.0	8.0	106	88.0
		15 to 19	5.6	4.1	12.2	8.7	162	124
		20 to 24	7.1	5.4	13.4	9.8	245	186
		25 to 29	9.8	8.0	16.4	13.0	418	328
		≥30	14.0	10.8	19.0	15.6	651	518

V. PATIENT-SPECIFIC DOSIMETRY

Because most of the US DRLs are derived from standard phantom measurements and are used as benchmarks for comparing X-ray dose estimates from a given facility, they should not be used as a substitute for estimating specific doses delivered to a patient. For example, $CTDI_{100}$, $CTDI_w$, and $CTDI_{vol}$ are estimates of dose delivered to phantoms of a specified size and material. These metrics depend on the X-ray output of the CT scanner but do not represent patient dose. While the SSDE takes into account variation in patient size, it is still only an indicator of patient dose [30].

On occasion, the need may arise to estimate the dose delivered to an individual patient because of a specific situation (eg, pregnancy, prolonged fluoroscopy, multiple examinations). In these situations it is recommended that the physician consider executing a formal written medical physics consultation with the Qualified Medical Physicist. Using the specific X-ray parameters of the diagnostic examination, the Qualified Medical Physicist can render an estimate of the specific dose to a given location in the patient, such as the location of the embryo or fetus, the patient's midline, or the patient's skin [31]. The consultation request should be signed by the requesting physician. The Qualified Medical Physicist's report should be signed by the Qualified Medical Physicist and should be incorporated into the patient's medical record. DRLs or ADs should not be used for patient dose estimates.

VI. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, registered radiologist assistants, radiologic technologists, and all supervising physicians have a responsibility for safety in the workplace by keeping radiation exposure to staff, and to society as a whole, "as low as reasonably achievable" (ALARA) and to assure that radiation doses to individual patients are appropriate, taking into account the possible risk from radiation exposure and the diagnostic image quality necessary to achieve the clinical objective. All personnel that work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection and application of dose limits) and the principles of proper management of radiation dose to patients (justification, optimization and the use of dose reference levels)

http://www-pub.iaea.org/MTCD/Publications/PDF/Pub1578_web-57265295.pdf

Nationally developed guidelines, such as the ACR's [Appropriateness Criteria](#)[®], should be used to help choose the most appropriate imaging procedures to prevent unwarranted radiation exposure.

Facilities should have and adhere to policies and procedures that require varying ionizing radiation examination protocols (plain radiography, fluoroscopy, interventional radiology, CT) to take into account patient body habitus (such as patient dimensions, weight, or body mass index) to optimize the relationship between minimal radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used whenever appropriate. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available at the Image Gently[®] for children (www.imagegently.org) and Image Wisely[®] for adults (www.imagewisely.org) websites. These advocacy and awareness campaigns provide free educational materials for all stakeholders involved in imaging (patients, technologists, referring providers, medical physicists, and radiologists).

Radiation exposures or other dose indices should be measured and patient radiation dose estimated for representative examinations and types of patients by a Qualified Medical Physicist in accordance with the applicable ACR technical standards. Regular auditing of patient dose indices should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry, the NCRP Report No. 172, Reference Levels and Achievable Doses in Medical and Dental Imaging: Recommendations for the United States or the Conference of Radiation Control Program Director's National Evaluation of X-ray Trends. (ACR Resolution 17 adopted in 2006 – revised in 2009, 2013, Resolution 52).

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

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 appearing under the heading *Position Statement on QC & Improvement, Safety, Infection Control, and Patient Education* on the ACR website (<https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards>).

Performance evaluation, quality control, acceptance testing, written survey reports, and follow-up procedures should be in accordance with the appropriate ACR Medical Physics Technical Standards (<https://www.acr.org/Clinical-Resources/Practice-Parameters-and-Technical-Standards>).

The Qualified Medical Physicist's annual survey report should include estimates of radiation dose for representative examinations and types of patients (eg, adults, pediatric) as applicable. The Qualified Medical Physicist should also compare these values with current DRLs and provide recommendations for improvement if *the dose estimates exceed the DRLs or are so low that may yield images of insufficient quality for the diagnostic task*.

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Principal Reviewer: Priscilla F. Butler, MS, FACR, FAAPM

Collaborative Committee – members represent their societies in the initial and final revision of this practice parameter

ACR

Maxwell R. Amurao, PhD, MBA, Chair
Caridad Borrás, DSc, FACR, FAAPM, FIOMP
Priscilla F. Butler, MS, FACR, FAAPM
Lynn Ansley Fordham, MD, FACR
Sarah McKenney, PhD

AAPM

Joel E. Gray, PhD, FAAPM, FACMP
Melissa C. Martin, MS, FACR, FAAPM, FACMP
Mark S. Rzeszotarski, PhD, FAAPM

SPR

A. Luana Stanescu, MD
David W. Swenson, MD

Committee on Practice Parameters and Technical Standards – Medical Physics

(ACR Committee responsible for sponsoring the draft through the process)

Maxwell R. Amurao, PhD, MBA, Chair
Charles M. Able, MS
Ishtiaq H. Bercha, MSc
Caridad Borrás, DSc, FACR, FAAPM, FIOMP
Chee-Wai Cheng, PhD, FAAPM
William R. Geiser, MS
Loretta M. Johnson, PhD
Mary Ann Keenan, DMP

Ralph P. Lieto, MS, FACR, FAAPM
Lijun Ma, PhD, FAAPM
Jonathon A. Nye, PhD
Matthew A. Pacella, MS, FACR
Anshuman Panda, PhD
Premavathy Rassiah, PhD
Thomas G. Ruckdeschel, MS
Christopher J. Watchman, PhD

Committee on Practice Parameters – Pediatric Radiology

(ACR Committee responsible for sponsoring the draft through the process)

Beverley Newman, MB, BCh, BSc, FACR, Chair
Lorna P. Browne, MB, BCh
Timothy J. Carmody, MD, FACR
Brian D. Coley, MD, FACR
Lee K. Collins, MD
Monica S. Epelman, MD
Lynn Ansley Fordham, MD, FACR
Kerri A. Highmore, MD

Sue C. Kaste, DO
Tal Laor, MD
Terry L. Levin, MD, FACR
Marguerite T. Parisi, MD, MS
Sumit Pruthi, MBBS
Nancy K. Rollins, MD
Pallavi Sagar, MD

Richard A. Geise, PhD, FACR, FAAPM, Chair, Commission on Medical Physics
Marta Hernanz-Schulman, MD, FACR, Chair, Commission on Pediatric Radiology
Jacqueline Anne Bello, MD, FACR, Chair, Commission on Quality and Safety
Matthew S. Pollack, MD, FACR, Chair, Committee on Practice Parameters and Technical Standards

Comments Reconciliation Committee

Samir B. Patel, MD, FACR, Chair
Beth A. Schueler, PhD, FACR, FAAPM, Co-Chair
Maxwell R. Amurao, PhD, MBA
Kimberly E. Applegate, MD, MS, FACR
Jacqueline Anne Bello, MD, FACR
Caridad Borrás, DSc, FACR, FAAPM, FIOMP
Priscilla F. Butler, MS, FACR, FAAPM
Richard Duszak, Jr., MD, FACR
Lynn Ansley Fordham, MD, FACR
Richard A. Geise, PhD, FACR, FAAPM
Joel E. Gray, PhD, FAAPM, FACMP
Marta Hernanz-Schulman, MD, FACR

Ralph P. Lieto, MS, FACR, FAAPM
Xinming Liu, PhD
Rebecca M. Marsh, PhD
Melissa C. Martin, MS, FACR, FAAPM, FACMP
Sarah McKenney, PhD
Beverley Newman, MB, BCh, BSc, FACR
Matthew S. Pollack, MD, FACR
Mark S. Rzeszotarski, PhD, FAAPM
A. Luana Stanescu, MD
Timothy L. Swan, MD, FACR, FSIR
David W. Swenson, MD
Joshua M. Wilson, PhD

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