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

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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.

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 care[1]. 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 practitioner considering all the circumstances presented. Thus, an approach that differs from the guidance in this document, 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 this document when, in the reasonable judgment of the practitioner, such course of action is indicated by variables such as the condition of the patient, limitations of available resources, or advances in knowledge or technology after publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document may consider documenting in the patient record information sufficient to explain the approach taken.

The practice of medicine involves the science, and 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 the guidance in this document 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 purpose of this document is to assist practitioners in achieving this objective.

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1 *Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, 831 N.W.2d 826 (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).

This practice parameter summarizes relevant existing US national diagnostic reference level (DRL) and achievable dose (AD) values and provides guidance and advice to physicians, Nonphysician Radiology Providers, Other Ancillary Personnel [1], and Qualified Medical Physicists on the implementation of these reference levels in the practice of medical X-ray imaging. DRL values are not provided for all current examinations due to a lack of

current data in the literature.

A DRL value is a form of investigation level used as a tool to aid optimization of protection in the medical exposure of patients for diagnostic and interventional procedures [2-10]. The International Commission on Radiological Protection (ICRP) defines the "DRL process" as the cyclical process of establishing DRL values, using them as a tool for optimization, and then determining updated DRL values as tools for further optimization [4]. DRL values are suggested action levels above which a facility should review its methods and determine if acceptable image quality can be achieved at lower doses. DRL values can be developed on a national level (National DRL) or on a local level (Local DRL) when no national DRL value is available [4]. For conciseness within this practice parameter, we use the term "DRL" to refer to "National Diagnostic Reference Levels." The ICRP emphasizes that DRL values are "not for regulatory or commercial purposes, not a dose restraint and not linked to limits or constraints [4]." The specific purpose of DRL and AD values is to provide benchmarks for comparison, not to define maximum or minimum dose limits.

DRL values are based on patient or standard phantom measurements under specific conditions at a number of representative clinical facilities. ICRP 135 [4] defines national DRL values as "the third quartile (75th percentile) of the distribution of the median values of the appropriate DRL quantity observed at each health care facility." This means that the median value for the procedure, as performed at participating institutions, is at or below the DRL value for three-fourths of those institutions. The ICRP also emphasizes that DRL values should not be applied to individual patients [4]. To make meaningful comparisons, facility median values for representative samples of patients of a particular group defined by the DRL values should be compared against these DRL values. Facilities must first ensure that they have sufficient data to yield a representative sample for their specific practice.

AD values are set at the 50th percentile of the distribution of facility median examination doses (ie, half of the facilities are producing images at lower doses and half are using higher doses). Further information on the AD process is available in the National Council on Radiation Protection and Measurements (NCRP) Report 172 [7] and ICRP 135 [4]. AD values can be used with DRL values to assist in optimizing image quality and dose.

The goal of clinical X-ray imaging is to obtain images of adequate quality to successfully complete a clinical task, while doing so at an appropriate radiation dose to the patient. In digital radiography (including computed radiography) there has been evidence of "dose creep" [11] resulting from the substantially wider latitude of digital image receptors relative to analog imaging counterparts. Adequate image quality must be assessed and monitored by the clinicians reading the studies. Excessive radiation dose in digital imaging may result in improved signal-to-noise ratio with a perceived improvement in image quality. Often it is only through monitoring radiation dose indexes, or surrogates thereof, that higher than warranted radiation doses are identified, relative to an established target.

However, it is important to note that too low of a radiation dose may result in inadequate image quality for the imaging task. The references used to develop DRL and AD values 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 AD values referenced in this practice parameter. Consequently, lower level dose investigation benchmarks are not provided in this document. Facilities with patient doses substantially below the AD values 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 suboptimal quality that may be detrimental to patient care [4,7].

European discussions have focused on developing national DRL values based on clinical indication rather than anatomic location because imaging protocols (and needed dose) differ with varying imaging goals [12,13]. The current national published data on US DRL values do not consistently break out examinations based on clinical indication. Furthermore, until CT scanners and other imaging equipment can automatically provide clinical indications to the US registry, patient-based DRL values for clinical indications will not be available.

Previous studies have shown that implementing the DRL process has contributed to lowering radiation dose to patients. For example, 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 DRL values 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 [14]. A Canadian study (Nova Scotia) published in 2017 showed that DRL implementation contributed to as much as a 41% reduction in CT patient dose without resulting in degradation of image quality [15]. A study in France reported a 27.4% decrease in the 75th percentile value of air kerma-area product for chest radiography between 2004 and 2015, with the number of flat panel detectors increasing from 6% to 43% [12].

The US DRL and AD values presented in this practice parameter are based on the most recently published national data from radiology procedures acquired from a variety of practices. If national dose studies for particular procedures have not been published, DRL and AD values are not provided for them in this document. Unfortunately, the most recent national data available for some procedures are from publications older than 10 years; consequently, these DRL and AD values should be used by facilities with caution when comparing against dose information acquired from more modern imaging systems. Although DRL and AD values for dental imaging procedures are not provided in this document, there are several publications that provide this relevant dose information [7,16,17].

The DRL and AD process is part of optimizing medical imaging. Optimization must balance image quality and patient dose (ie, image quality must be maintained at an appropriate level as radiation doses are decreased). In addition to optimizing patient radiation dose and image quality, the use of this practice parameter should also help to maximize the efficacy of these procedures, minimize radiation dose to staff, maintain safety conditions, and ensure compliance with applicable regulations. The implementation of the DRL process [4] in medical X-ray 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. 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.

II. 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, Diagnostic Radiology or Interventional Radiology/Diagnostic Radiology (IR/DR) 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. For radiography, the physician should meet the personnel qualifications outlined in the ACR-AAPM-SIIM-SPR Practice Parameter for Digital Radiography [18]. For fluoroscopy, the physician should meet the personnel qualifications outlined in the ACR–AAPM Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures [1]. For CT, the physician should meet the personnel qualifications outlined in the ACR–SPR Practice Parameter for Performing and Interpreting Diagnostic Computed Tomography (CT) [19].

and

3. The physician should have documented training in and understanding of the physics of X-ray imaging (including radiography, fluoroscopy, and CT) and experience with the equipment needed to safely produce images of adequate quality, which includes generation of the X-ray beam, image receptor technology, and image processing.

The physician is the principal individual involved in establishing and implementing the DRL process in medical imaging using ionizing radiation. The physician should work closely with a Qualified Medical Physicist in this process. The clinical objectives of all medical X-ray 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 [20].

II. QUALIFICATIONS AND RESPONSIBILITIES OF PERSONNEL

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 (CCPM), the American Board of Science in Nuclear Medicine (ABSNM), or the American Board of Medical Physics (ABMP).

A Qualified Medical Physicist should meet the ACR Practice Parameter for Continuing Medical Education (CME) [20].

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). (ACR Resolution 17, adopted in 1996 – revised in 2008, 2012, 2022 Resolution 41f)
The Qualified Medical Physicist's CME should include 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 the typical clinical procedures performed where medical physics services are provided.

III. DIAGNOSTIC REFERENCE LCEVELS AND ACHIEVABLE DOSES FOR X-RAY IMAGING

As explained in the NCRP Report 172, national DRL and AD values have decreased substantially 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 collection of NEXT data, which was in 2006 [21]. Essentially all radiology departments have converted from screen film to CT and digital radiography. In fluoroscopy, many institutions have converted to flat panel detectors with a wider range of operating modes and beam filtrations. Some of the DRL and AD values in this practice parameter are based on the most current NEXT studies because this is the only nationwide survey data from the United States currently available for some examinations. However, the data in many of these studies are over 20 years old, and these

DRL and AD values should be used recognizing this. Other sources of more current dose information may be available from geographically localized studies (eg, the state of Michigan) [22]. More current data are available for the development of CT DRL and AD values [23,24].

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

III. DIAGNOSTIC REFERENCE LCEVELS AND ACHIEVABLE DOSES FOR X-RAY IMAGING

A. Radiography

For radiography, including digital imaging and screen-film, this practice parameter bases DRL and AD values on a measurement of incident air kerma free-in-air ($K_{a,i}$) [25] at the entrance skin plane to a standard phantom using the X-ray image acquisition parameters the facility would typically select for an average-sized adult or pediatric patient [7]. DRL values are provided for 5 radiographic projections (Table 1).

The phantoms and details of measurements are provided in NCRP Report 172 and the appropriate NEXT reports [7,17]. The sizes of the adult and pediatric patients modeled by the phantoms are given in Table 1. The adult chest DRL and AD values are based on NEXT data collected in 2001; the pediatric chest DRL and AD values are based on NEXT data collected in 1998; and the adult abdomen and lumbosacral spine DRL and AD values are based on NEXT data collected in 2002. Because technology and procedures rapidly improve over time in modern imaging, caution should be used when comparing facility data against DRL values derived from data more than 10 years old. Doses in clinical practice may be significantly smaller. Work to collect and evaluate national doses from radiography procedures using the ACR Dose Index Registry [26] is ongoing and will be used to update this practice parameter in future revisions. For more current data from a geographically localized study, see the state of Michigan website [22].

Table 1
Phantom-Based AD and DRL Values* for Adult and Pediatric X-Ray Examinations
(incident air kerma, free-in-air ($K_{a,i}$)) [7]

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

* Because technology and procedures rapidly improve over time in modern imaging, caution should be used when comparing facility data against DRL values derived from data over 10 years old.

III. DIAGNOSTIC REFERENCE LCEVELS AND ACHIEVABLE DOSES FOR X-RAY IMAGING

B. Fluoroscopy

DRL and AD values are not provided for fluoroscopy in the update of this practice parameter . The existing US nationwide dose information for fluoroscopic procedures was collected almost 20 years ago and DRL and AD

values derived from this data should not be applied to modern fluoroscopic systems currently in use. Doses in current clinical practice will most likely be significantly smaller. Facilities using older fluoroscopic systems can refer to the DRL and AD values published in NCRP Report 172 and the appropriate NEXT Reports [7,17].

Work to collect and evaluate national doses from fluoroscopy procedures using the ACR Dose Index Registry [27] is ongoing and will be used to update this practice parameter in future revisions. More current data from limited populations of pediatric and adult patients are available [28-31].

III. DIAGNOSTIC REFERENCE LCEVELS AND ACHIEVABLE DOSES FOR X-RAY IMAGING

C. CT

Two sets of DRL and AD values are provided for both adult and pediatric CT, one developed from actual patient data and the second from phantom data . Because US DRL values have historically been based on phantom data and the national collection and analysis of patient data is relatively new, both are included. These benchmarks are based on the volume CT dose index ($CTDI_{vol}$), which has been defined by the International Electrotechnical Commission [32].

Table 2 presents patient-based adult CT DRL and AD values presented as $CTDI_{vol}$, size-specific dose estimates (SSDEs) [33], and dose length products (DLPs) [34]. These benchmarks are the result of an analysis of the top 10 adult CT examinations submitted to the ACR Dose Index Registry [26]. These examinations included 1.3 million examinations performed at 583 facilities in 2014 [24]. The DRL and AD values are presented for the median patient sizes determined from localizer images [35,36] submitted with the dose parameters for each examination. (A broader range of size-specific DRL and AD values 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 [37] for all other examinations. For body examinations, the water-equivalent diameter was used to determine the appropriate conversion factor to estimate SSDE from $CTDI_{vol}$ normalized to a 32-cm phantom [22]; all head and neck examinations were standardized to a 16-cm phantom. (Because SSDE conversion factors for head and neck examinations were not available at the time this study was published, they are not included in the table.)

Table 2
Patient-Size-Based AD and DRL Values for Adult CT [24]

Examination	Patient Size (cm)	$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy-cm)	
		AD	DRL	AD	DRL	AD	DRL
Head and brain without contrast material	14 to 16 (lat thickness)	49	56			811	962
Neck with contrast material	18 to 22 (water-eq dia)	15	19			429	563
Cervical spine without contrast material	17 to 21 (water-eq dia)	20	28			421	562
Chest without contrast material	29 to 33 (water-eq dia)	9	12	11	15	334	443
Chest with contrast material	29 to 33 (water-eq dia)	10	13	11	15	353	469
Chest pulmonary arteries with contrast material	29 to 33 (water-eq dia)	11	14	13	17	357	445
Abdomen and pelvis without contrast material	29 to 33 (water-eq dia)	13	16	15	19	639	781
Abdomen and pelvis with contrast material	29 to 33 (water-eq dia)	12	15	15	18	608	755
Abdomen, pelvis, and kidney without contrast material	29 to 33 (water-eq dia)	12	15	14	19	576	705

Chest, abdomen, and pelvis with contrast material	29 to 33 (water-eq dia)	12	15	14	18	779	947

Tables 3 and 4 present patient age-based and size-based pediatric CT DRL and AD values presented as $CTDI_{vol}$ and DLP [34]. (Although the ICRP recommends that pediatric DRL values be weight-based [4], this was not possible with the US analysis because the ACR Dose Index Registry [26] does not collect patient weight.) As with the adult DRL values, these benchmarks are the result of an analysis of the top 10 pediatric CT examinations submitted to the ACR Dose Index Registry [26]. These examinations included more than 1.5 million examinations performed at 1625 facilities from 2016 to 2020 [24].

Table 3
Patient Age-Based DRL and AD Values for Pediatric CT [23]

Examination		$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy-cm)	
	Age (y)	AD	DRL	AD	DRL	AD	DRL
Head without contrast material	0-<1	19	23			267	344
	1-<2	22	27			350	440
	2-<6	25	31			409	518
	6-18	46	55			748	910
Sinuses without contrast material	0-<1	-	-			-	-
	1-<2	-	-			-	-
	2-<6	6.7	12			94	219
	6-18	14	22			209	377
Maxillofacial area without contrast material	0-<1	6.3	12			103	155
	1-<2	7.0	15			127	286
	2-<6	11	23			196	472
	6-18	24	34			480	647
Neck soft tissue with contrast material	0-<1	2.5	3.8			41	58
	1-<5	3.4	4.4			65	88
	5-<10	4.6	6.3			98	137
	10-<15	7.8	11			198	270
	15-18	10	14			300	385
Cervical spine without contrast material	0-<1	5.1	17			81	260
	1-<5	4.7	11			67	179
	5-<10	6.7	12			121	241
	10-<15	13	24			284	490
	15-18	19	34			425	707
Chest without contrast material	0-<1	1.2	1.7	2.9	3.8	22	27
	1-<5	1.7	2.2	3.3	3.9	35	49
	5-<10	2.1	2.5	3.7	4.6	57	70
	10-<15	3.4	4.1	5.1	6.2	107	128
	15-18	5.9	7.4	7.7	9.3	202	257

Examination		$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy-cm)	
	Age (y)	AD	DRL	AD	DRL	AD	DRL
Chest with contrast material	0-<1	1.4	1.6	3.0	4.1	23	31
	1-<5	1.8	2.4	3.6	4.5	43	58
	5-<10	2.3	2.9	3.8	5.1	64	95
	10-<15	4.6	7.2	6.3	9.1	146	272
	15-18	8.8	14	11	16	364	596
Abdomen and pelvis without contrast material	0-<1	-	-	-	-	-	-
	1-<5	2.2	2.6	4.5	5.4	69	95
	5-<10	3.4	4.8	5.9	7.9	124	171
	10-<15	6.2	8.1	8.9	11	277	367
	15-18	8.4	11	11	14	408	510
Abdomen and pelvis with contrast material	0-<1	1.8	2.4	4.2	5.3	49	60
	1-<5	2.4	2.9	4.6	5.9	79	100
	5-<10	3.3	4.6	5.8	8.0	126	170
	10-<15	6.2	7.9	8.9	11	276	358
	15-18	8.3	11	11	14	402	511
Chest, abdomen, and pelvis with contrast material	0-<1	2.0	2.7	4.4	6.4	62	89
	1-<5	2.2	3.0	4.4	5.3	87	109
	5-<10	2.9	4.3	4.7	7.0	142	204
	10-<15	5.9	9.1	8.0	12	321	437
	15-18	12	17	14	21	691	964

Note: Blank cells indicate that the bin had fewer than 5 facilities reporting 20 or more examinations.

The patient size information in Table 4 is presented as effective diameter [37]. For body examinations, the effective diameter was used to determine the appropriate conversion factor to estimate SSDE from $CTDI_{vol}$ normalized to a 32-cm phantom [23]; all head and neck examinations were standardized to a 16 cm phantom.

Table 4
Patient Size-Based DRL and AD Values for Pediatric CT [23]

Examination	Eff Dia	$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy-cm)	
	(cm)	AD	DRL	AD	DRL	AD	DRL
Chest without contrast material	12-<16	1.7	1.9	3.7	4.2	29	41
	16-<20	1.9	2.5	3.7	4.7	50	63
	20-<24	2.5	3.2	4.0	5.1	81	106
	24-<28	3.5	4.5	4.8	6.5	122	154
	28-<32	4.5	6.0	5.7	7.5	160	186
	32-<36	5.7	7.4	6.0	7.9	213	249
	36-<40	-	-	-	-	-	-
	>40	-	-	-	-	-	-
Chest with contrast material	12-<16	1.5	2.0	3.3	4.4	30	42
	16-<20	2.0	2.6	3.9	5.0	53	67
	20-<24	2.5	3.4	4.2	5.5	78	107
	24-<28	4.7	6.1	6.6	8.5	159	260
	28-<32	7.2	12	8.9	15	268	480
	32-<36	9.2	13	10	15	392	592
	36-<40	8.1	15	7.8	13	295	538
	>40	12	13	8.9	9.3	417	568
Abdomen and pelvis without contrast material	12-<16	2.1	2.6	4.6	5.4	58	79
	16-<20	2.7	3.5	5.1	6.9	96	137
	20-<24	4.8	6.1	7.7	9.8	199	272
	24-<28	6.4	8.4	9.1	12	287	409
	28-<32	8.9	11	11	14	423	538
	32-<36	13	16	14	17	677	824
	36-<40	17	21	16	20	910	1,050
	>40	24	28	15	21	1,155	1,342
Abdomen and pelvis with contrast material	12-<16	2.0	2.7	4.2	5.7	63	83
	16-<20	2.9	4.1	5.4	7.6	109	148
	20-<24	4.8	5.8	7.8	9.4	209	261
	24-<28	6.5	8.0	9.3	12	304	380
	28-<32	8.8	11	11	13	433	535
	32-<36	12	16	13	17	641	808
	36-<40	16	20	15	19	817	1026
	>40	21	26	15	18	1091	1292
Chest, abdomen, and pelvis with contrast material	12-<16	2.0	2.8	4.4	5.9	75	94
	16-<20	2.4	3.4	4.6	6.9	104	130
	20-<24	3.8	4.4	6.1	7.2	179	246
	24-<28	6.9	9.1	9.8	13	396	526
	28-<32	8.9	12	11	15	538	673

Examination	Eff Dia	$CTDI_{vol}$ (mGy)		SSDE (mGy)		DLP (mGy-cm)	
	(cm)	AD	DRL	AD	DRL	AD	DRL
	32-<36	11	19	12	20	711	871
	36-<40	14	16	13	14	909	970
	>40	13	21	9.3	14	905	1,349

Note: Blank cells indicate that the bin had fewer than 5 facilities reporting 20 or more examinations.

The phantom-based DRL and AD values presented in Table 5 were derived from analysis of the data gathered from the first 3 years of the ACR CT Accreditation Program [38,39], from the evaluation of more current CT Accreditation Program data [40], 2005 CT NEXT data, and NCRP Report 172. The lateral dimensions are for average-sized patients of the specified age [41]. A 16-cm-diameter polymethyl methacrylate cylinder 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 DRL and AD values are provided for pediatric abdomen examinations.

Table 5
Phantom-Based DRL and AD Values for Adult and Pediatric CT ($CTDI_{vol}$)

Examination	Patient Lateral Dimension (cm)	CTDI Phantom Diameter (cm)	CTDIvol	
			AD (mGy)	DRL (mGy)
Adult head [7,39]	16	16	57	75
Adult abdomen-pelvis [7,39]	38	32	17	25
Adult chest [7]	35	32	14	21
Pediatric 1-year-old head [40]	15	16	*	35
Pediatric 5-year-old abdomen-pelvis [40]	20	16	*	15
		32	*	7.5

**AD values are not available for pediatric studies from source reference.*

IV. PATIENT-SPECIFIC DOSIMETRY

Because many of the US DRL values 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, CTDI100, CTDIw, and CTDIvol are based upon air kerma measurements inside cylindrical polymethyl methacrylate (PMMA) phantoms. These metrics depend on the X-ray output of the CT scanner but do not represent patient dose. Although the SSDE takes into account variation in patient size, it is still not patient dose [42].

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 [43]. Using the specific X-ray parameters of the imaging 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 [44-46]. The Qualified Medical Physicist's report should be signed by the Qualified Medical Physicist and should be incorporated into the patient's medical record. DRL or AD values should not be used for patient dose estimates.

V. DOCUMENTATION

Reporting should be in accordance with the ACR Practice Parameter for Communication of Diagnostic Imaging

Findings [47].

VI. RADIATION SAFETY IN IMAGING

Radiologists, medical physicists, non-physician radiology providers**,** 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 who work with ionizing radiation must understand the key principles of occupational and public radiation protection (justification, optimization of protection, application of dose constraints and limits) and the principles of proper management of radiation dose to patients (justification, optimization including the use of dose reference levels). https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1775_web.pdf

Nationally developed guidelines, such as the ACR's Appropriateness Criteria®, should be used to help choose the most appropriate imaging procedures to prevent unnecessary radiation exposure.

Facilities should have and adhere to policies and procedures that require ionizing radiation examination protocols (radiography, fluoroscopy, interventional radiology, CT) to vary according to diagnostic requirements and patient body habitus to optimize the relationship between appropriate radiation dose and adequate image quality. Automated dose reduction technologies available on imaging equipment should be used, except when inappropriate for a specific exam. If such technology is not available, appropriate manual techniques should be used.

Additional information regarding patient radiation safety in imaging is available from the following websites – Image Gently® for children (www.imagegently.org) and Image Wisely® for adults (www.imagewisely.org). 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 periodically measured by a Qualified Medical Physicist in accordance with the applicable ACR Technical Standards. Monitoring or regular review of dose indices from patient imaging should be performed by comparing the facility's dose information with national benchmarks, such as the ACR Dose Index Registry and relevant publications relying on its data, applicable ACR Practice Parameters, 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; 2006, 2009, amended 2013, revised 2023 (Res. 2d).

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/Advocacy-and-Economics/ACR-Position-Statements/Quality-Control-and-Improvement).

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 DRL values and provide recommendations for improvement if *the dose estimates exceed the DRL values or are so low that may yield images of insufficient quality for the medical imaging task.*

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