



Diagnostic Reference Levels

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Introduction

Diagnostic reference levels were first mentioned by the International Commission on Radiological Protection (ICRP) in 1990¹ and subsequently recommended in greater detail in 1996². From the 1996 report:

The Commission now recommends the use of diagnostic reference levels for patients. These levels, which are a form of investigation level, apply to an easily measured quantity, usually the absorbed dose in air, or in a tissue equivalent material at the surface of a simple standard phantom or representative patient. . . . [T]he diagnostic reference level will be intended for use as a simple test for identifying situations where the level of patient dose or administered activity is unusually high. If it is found that procedures are consistently causing the relevant diagnostic reference level to be exceeded, there should be a local review of procedures and the equipment in order to determine whether the protection has been adequately optimized. If not, measures aimed at reduction of doses should be taken.

Diagnostic reference levels are supplements to professional judgment and do not provide a dividing line between good and bad medicine. It is inappropriate to use them for regulatory or commercial purposes. Diagnostic reference levels apply to medical exposure, not to occupational and public exposure. Thus, they have no link to dose limits or constraints. Ideally, they should be the result of a generic optimization of protection. In practice, this is unrealistically difficult and it is simpler to choose the initial values as a percentile point on the observed distribution of doses to patients. The values should be selected by professional medical bodies and reviewed at intervals that represent a compromise between the necessary stability and the long-term changes in the observed dose distributions. The selected values will be specific to a country or region.

Diagnostic reference levels are not the suggested or ideal dose for a particular procedure or an absolute upper limit for dose. Rather, they represent the dose level at which an investigation of the appropriateness of the dose should be initiated. In conjunction with an image quality assessment, a qualified medical physicist should work with the radiologist and technologist to determine whether or not the required level of image quality could be attained at lower dose levels. Thus, reference levels act as “trigger levels” to initiate quality improvement. Their primary value is to identify dose levels that may be unnecessarily high – that is, to identify those situations where it may be possible to reduce dose without compromising the required level of image quality.



Use of Diagnostic Reference Levels to Reduce Patient Dose

The use of diagnostic reference levels as an important dose optimization tool is endorsed by many professional and regulatory organizations, including the ICRP, American College of Radiology (ACR), American Association of Physicists in Medicine (AAPM), United Kingdom (U.K.) Health Protection Agency, International Atomic Energy Agency (IAEA), and European Commission (EC). Reference levels are typically set at the 75th percentile of the dose distribution from a survey conducted across a broad user base (i.e., large and small facilities, public and private, hospital and out-patient) using a specified dose measurement protocol and phantom. They are established both regionally and nationally, and considerable variations have been seen across both regions and countries³. Dose surveys should be repeated periodically to establish new reference levels, which can demonstrate changes in both the mean and standard deviation of the dose distribution.

The use of diagnostic reference levels has been shown to reduce the overall dose and the range of doses observed in clinical practice. For example, U.K. national dose surveys demonstrated a 30% decrease in typical radiographic doses from 1984 to 1995 and an average drop of about 50% between 1985 and 2000^{4,5}. While improvements in equipment dose efficiency may be reflected in these dose reductions, investigations triggered when a reference dose is exceeded can often determine dose reduction strategies that do not negatively impact the overall quality of the specific diagnostic exam. Thus, data points above the 75th percentile are, over time, moved below the 75th percentile – with the net effect of a narrower dose distribution and a lower mean dose.

CT Diagnostic Reference Levels From Other Countries

Diagnostic reference levels must be defined in terms of an easily and reproducibly measured dose metric using technique parameters that reflect those used in a site's clinical practice. In radiographic and fluoroscopic imaging, typically measured quantities are entrance skin dose for radiography and dose area product for fluoroscopy. Dose can be measured directly with TLD or derived from exposure measurements. Some authors survey typical technique factors and model the dose metric of interest.

In CT, published diagnostic reference levels use CTDI-based metrics such as CTDI_w, CTDI_{vol}, and DLP. Normalized CTDI values (CTDI per mAs) can be used by multiplying them by typical technique factors, or CTDI values can be measured at the typical clinical technique factors. Tables 1 and 2 below provide a summary of CT reference levels from a variety of national dose surveys.

CT Diagnostic Reference Levels From the ACR CT Accreditation Program

Beginning in 2002, the ACR CT Accreditation Program has required sites undergoing the accreditation process to measure and report CTDI_w and CTDI_{vol} for the head and body CTDI phantoms. The typical acquisition parameters for a site's adult head (head), pediatric abdomen (ped), and adult abdomen (body) examinations were



used to calculate CTDI_w and CTDI_{vol}. For the pediatric exam, sites were instructed to assume the size and weight of a typical 5-year-old child, and doses were measured using the 16-cm phantom. The average and standard deviation of these doses were calculated by year. Summary data for CTDI_{vol} are shown in Table 3 below.

In every case except adult abdomen exams in 2003, both the average dose and the standard deviation fell for each consecutive year. Thus, the establishment of CT reference levels in the United States appears to have helped reduce both the mean dose and the range of doses for these common CT examinations.

Although dose reduction was observed for adult head CT examinations, feedback from sites undergoing accreditation indicated that sites were systematically reducing dose to below the 60 mGy level, even though complaints with regard to head image quality at this dose level were common. The purpose of reference levels is to decrease dose levels only when doing so does not compromise image quality or patient care. Changes in technology (multi-detector-row CT) and practice (3-5 mm image widths) have occurred since the U.K. dose survey that gave rise to the 60 mGy level for the adult head.

As can be seen in Tables 1 and 2, these changes have resulted in an increase in the diagnostic reference level for head CT (U.K. 2003 data now specifies CTDI_{vol} reference levels of 65 mGy for the cerebrum and 100 mGy for the posterior fossa). Thus, the ACR CT Accreditation Program used survey data from the inception of the program to establish the most current U.S. reference levels for head CT (i.e., 2002 data were used to avoid including dose values that were thought to yield inadequate image quality). Beginning January 1, 2008, the ACR CT reference levels were changed to a CTDI_{vol} of 75 mGy (adult head), 25 mGy (adult abdomen) and 20 mGy (pediatric abdomen)¹⁵. These values will be reassessed periodically.

CT Diagnostic Reference Levels for Other CT Applications

Because the practice of CT encompasses many more exam types than routine head and body exams, reference levels for many common CT examinations are important for continuing dose optimization efforts in CT. To this end, several national surveys have begun to assess a broader range of exam types. Additionally, the ACR has begun a project to automatically collect CTDI_{vol} data directly from the DICOM header, thus allowing considerably faster accumulation of data sufficient to establish reference levels for additional exam types. This information will extend the value of the diagnostic reference level concept to the majority of CT applications, enabling individual CT users and the community at large to answer the question, “What doses are typical and what doses are too much?”



Table 1

Adult Diagnostic Reference Levels for CTDI _w (mGy) and DLP (mGy·cm)								
	Head		Abdomen		Abdomen & Pelvis			
	Whole Exam		Whole Exam		Pelvis		Whole Exam	
	CTDI _w	DLP	CTDI _w	DLP	CTDI _w	DLP	CTDI _w	DLP
EC 1999 ⁶	60	1050	35	900	-	-	35	780
ACR 2002 ⁷	60	-	35	-	-	-	-	-
UK 2003 ⁸	-	930	20	470	-	-	20	560
Germany 2003 ⁹	60	1050	25	770	-	-	24	1500
Switzerland ¹⁰ 2004	60	800	20	710	30	540	-	-
Taiwan 2007 ¹¹	72	850	31	680	28	520	-	-

EC = European Commission; ACR = American College of Radiology; UK = United Kingdom

Table 2

Adult Diagnostic Reference Levels for CTDI _{vol} (mGy) and DLP (mGy·cm)								
	Head		Abdomen		Abdomen & Pelvis			
	Whole Exam		Whole Exam		Pelvis		Whole Exam	
	CTDI _{vol}	DLP	CTDI _{vol}	DLP	CTDI _{vol}	DLP	CTDI _{vol}	DLP
Sweden 2002 ¹²	75	1200	25	-	-	-	-	-
UK 2003 ⁸	65 - 100	930	14	470	-	-	14	560
Netherlands 2008 ¹³	-	-	-	-	-	-	15	700
EC 2004 ¹⁴	60	-	25	-	-	-	15	700
ACR 2008 ¹⁵	75	-	25	-	-	-	-	-

EC = European Commission; ACR = American College of Radiology; UK = United Kingdom



Table 3

CTDIvol (mGy) statistics from the first 3 years of the ACR CT Accreditation Program									
	2002	2003	2004	2002	2003	2004	2002	2003	2004
	Adult Head			Adult Abdomen			Pediatric Abdomen		
Mean	66.7	58.5	55.8	18.7	19.2	17.0	17.2	15.9	14.0
Std. Dev.	23.5	17.5	15.7	8.0	8.7	7.6	9.7	8.6	7.0
75 %tile	76.8	63.9	60.0	22.6	23.4	21.1	20.6	20.5	18.4
90 %tile	99.0	82.2	74.0	29.5	30.6	25.8	26.6	25.6	23.4

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