DIAGNOSTIC REFERENCE LEVELS IN MEDICAL IMAGING: REVIEW AND ADDITIONAL ADVICE

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Key Points

- **Diagnostic reference levels (DRLs) should be used by regional, national and local authorized bodies. The numerical values of DRLs are advisory, however, implementation of the DRL concept may be required by an authorized body.**
- **The concept of DRLs allows flexibility in their selection and implementation.**
- **The Committee 3 advice does not specify quantities, numerical values or details of implementation for DRLs. This is the task of the regional, national and local authorized bodies, each of which should meet the needs in its respective area.**
- **The Committee 3 rationale for its advice is that any reasonable and practical approach, consistent with the advice, will improve the management of patient doses in medical imaging.**

Introduction

(1) The purpose of this document is to provide additional advice to regional, national and local authorized bodies and the clinical community on the application of diagnostic reference levels as a practical tool in diagnostic radiology and nuclear medicine. Achieving acceptable image quality or adequate diagnostic information, consistent with the medical imaging task, is the overriding clinical objective. Diagnostic reference levels are then used to help manage the radiation dose to patients so that the dose is commensurate with the clinical purpose.

(2) A review was conducted of the various approaches that have been taken by authorized bodies, working in concert with professional medical groups, to establish diagnostic reference levels for medical imaging tasks. While the approaches are not uniform in aim and methodology, it is concluded that there are a variety of ways to implement the concept of diagnostic reference levels, depending on the medical imaging task of interest, the regional, national or local state of practice, and the regional, national or local preferences for technical implementation.

(3) The document briefly reviews the existing ICRP guidance, summarizes the information on approaches taken to date, and presents additional advice from ICRP Committee 3. The advice given here provides a framework for diagnostic reference levels that is consistent with earlier ICRP guidance, but allows more flexibility in their selection

and use. While some illustrative examples are given, the advice does not specify the quantities to be used, the numerical values to be set for the quantities, or the technical details of how regional, national or local authorized bodies should implement diagnostic reference levels.

Existing ICRP Guidance

(4) ICRP Publication 60 (ICRP, 1991) provided the following recommendation in the section on optimization of protection in medical exposure in paragraph (S34):
"Consideration should be given to the use of dose constraints, or investigation levels, selected by the appropriate professional or regulatory agency, for application in some common diagnostic procedures. They should be applied with flexibility to allow higher doses where indicated by sound clinical judgment."

(5) ICRP Publication 73 (ICRP, 1996) introduced the term "diagnostic reference level," explained its place in the broader ICRP concept of reference levels, and expanded the ICRP Publication 60 recommendation in (S34) in more detail [paragraphs (99) through (106) of ICRP Publication 73]. The main points are summarized below.

(a) The term used is diagnostic reference level.
(b) The purpose is advisory. It is a form of investigation level to identify unusually high levels, which calls for local review if consistently exceeded. In principle, there could be a lower level also (i.e. below which there is insufficient radiation dose to achieve a suitable medical image). Diagnostic reference levels are not for regulatory or commercial purposes, not a dose constraint, and not linked to limits or constraints.
(c) The examination types include diagnostic radiology and nuclear medicine (i.e. common exams and broadly defined types of equipment).
(d) Their selection is by professional medical bodies, using a percentile point on the observed distribution for patients, and specific to a country or region.
(e) The quantities should be easily measured, such as absorbed dose in air or tissue-equivalent material at the surface of a simple standard phantom or representative patient for diagnostic radiology, and administered activity for diagnostic nuclear medicine.

Review of Reference Levels in Medical Imaging

(6) There have been a number of approaches to reference levels used for medical imaging. Typically, reference levels are used as investigation levels (i.e. a quality assurance tool) and they are advisory. But, there are exceptions where the approach uses "achievable levels" indicative of more optimum conditions, mentions dose constraints, or incorporates a dose limit or suspension level (i.e. only for mammography used for screening). To clarify paragraph (5) (b), the numerical value of a diagnostic reference level is advisory (i.e. the numerical value is not for regulatory or commercial purposes, not a dose constraint, and not linked to limits or constraints). However, authorized bodies may require implementation of the concept of a diagnostic reference level.

(7) There have been fairly consistent criteria for selecting reference levels, although the criteria used to date differ for diagnostic radiology and nuclear medicine. In diagnostic radiology, reference levels usually have been derived from distributions of dosimetric quantities for patients observed in practice in the relevant region or country. Usually, only upper levels have been selected and lower levels have not been specified. In nuclear medicine, reference levels usually have been derived from pragmatic values of administered activity based on accepted custom and practice. Typically, all reference levels are developed through cooperation between radiation protection authorities and professional groups or specialists (i.e. clinical peer involvement).

(8) There have been different aims for various reference levels. While reference levels apply to a selected medical imaging task, often the clinical and technical conditions are not fully defined, with the degree of definition dependent on the aim. At least three general aims can be identified:

(a) To improve a regional, national or local distribution observed for a general medical imaging task, by identifying and reducing the number of unjustified high or low values in the distribution;
(b) To promote good practice for a more specific medical imaging task; and
(c) To promote an optimum range of values for a specified medical imaging protocol.

(9) There have been a number of different quantities used for reference levels. The quantity selected is dependent on the type of clinical procedure, for example, whether it is an individual radiographic projection, a procedure or examination consisting of multiple projections or field locations, or a diagnostic nuclear medicine procedure (i.e. a specific radiopharmaceutical and clinical purpose). The quantity used is also dependent on the body setting the reference level, and is related to the desired aim, local preference and the unique irradiation conditions.

(10) The observations given above highlight the array of considerations and approaches to reference levels, whose features are displayed in Table 1 (Approaches to Reference Levels) and Table 2 (Listing of Reference Levels), which is a listing of approaches and values that have been selected by a number of authorized bodies in recent years.[1] Tables 1 and 2 are for background information and are not part of the additional advice from Committee 3 given in paragraphs (12) through (23).

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[1] There are continuing efforts to develop and implement diagnostic reference levels throughout the world. A recent IAEA/EC/PAHO/WHO Conference (IAEA, 2001) included a number of papers on these developments in diagnostic radiology and nuclear medicine.

Underlying Considerations

(11) In order to interpret correctly the relationship between a change in the numerical value of a quantity used as a diagnostic reference level and the corresponding change in patient tissue doses that determine the relative patient risk, the following considerations are important:

(a) The numerical value of the diagnostic reference level should be tied to defined clinical and technical requirements for the medical imaging task. A selected numerical value for one situation may not be applicable to different clinical and technical requirements, even if the same area of the body is being imaged. The requirements can be general or specific.

(b) The relative tissue dose distribution in the body should not change appreciably among patients undergoing the selected medical imaging task. A proportional change in the measured quantity should correspond to a proportional and uniform percentage change in the individual tissue doses. If the relative tissue-dose distribution in the body is appreciably different from that used to establish the diagnostic reference level, due to a different field size, field location, beam quality or other technical factor that alters the internal dose distribution, then interpretation of a change in the measured quantity with regard to the change in tissue doses (and therefore the patient risk) would be ambiguous.

In setting diagnostic reference levels, regional, national and local authorized bodies and professional groups should be cognizant of these considerations.

Additional Advice on Diagnostic Reference Levels from ICRP Committee 3

Objective of a Diagnostic Reference Level

(12) The objective of a diagnostic reference level is to help avoid radiation dose to the patient that does not contribute to the clinical purpose of a medical imaging task. This is accomplished by comparison between the numerical value of the diagnostic reference level (derived from relevant regional, national or local data) and the mean or other appropriate value observed in practice for a suitable reference group of patients or a suitable reference phantom. A reference group of patients is usually defined within a certain range of physical parameters (e.g. height, weight). If an unselected sample of patients were used as a reference group, it would be difficult to interpret whether the observed value for the sample is higher or lower than the diagnostic reference level. A diagnostic reference level is not applied to individual patients.

Uses for a Diagnostic Reference Level

(13) A diagnostic reference level can be used:

(a) To improve a regional, national or local distribution of observed results for a ***general medical imaging task***, by reducing the frequency of unjustified high or low values;

(b) To promote attainment of a narrower range of values that represent good practice for a ***more specific medical imaging task***; or

(c) To promote attainment of an optimum range of values for a ***specified medical imaging protocol***.

Uses (13) (a), (b) and (c) are differentiated by the degree of specification for the clinical and technical conditions selected by the authorized body for a given medical imaging task.

(14) Appropriate local review and action is taken when the value observed in practice is consistently outside the selected upper or lower level. This process helps avoid unnecessary tissue doses being received by patients in general and, therefore, helps avoid unnecessary risk for the associated radiation health effects.

Definitions and Examples

(15) Definitions of the terms ***general medical imaging task***, ***more specific medical imaging task***, and ***specified medical imaging protocol*** are given below, along with examples of quantities and their application to diagnostic reference levels for the uses referred to in paragraphs (13) (a), (b) and (c). The examples do not constitute Committee 3 recommendations, however, they illustrate generally the additional Committee 3 advice.

(16) The term ***general medical imaging task*** refers to an imaging task for a general clinical purpose, with minimum specification of other factors, e.g. a posterioanterior (PA) chest radiograph with the clinical purpose and technique factors unspecified. Examples of quantities and their application to improve a regional, national or local distribution of observed values for a ***general medical imaging task*** [paragraph (13) (a)] are:

(a) Entrance surface air kerma (in air, no backscatter) or entrance surface dose (in a specified material, with backscatter) in mGy, for a given radiographic projection (e.g. PA chest);
(b) Dose area product (DAP) in mGy cm^2 for a given type of fluoroscopic examination that has a well-defined anatomical region of clinical study (e.g. barium enema); and
(c) Administered activity (A) in MBq for a given nuclear medicine imaging task using a given radiopharmaceutical (e.g. lung perfusion with Tc-99m MAA).

(17) The term ***more specific medical imaging task*** refers to an imaging task for a clearly defined clinical purpose, but allows for differences among medical facilities in other technical and clinical details, e.g. a PA chest radiograph with the clinical purpose and the general technique (such as high kVp) specified, but the detailed technique factors unspecified. Examples of quantities and their application to promote attainment of a narrower range of values that represent good practice for a ***more specific medical imaging task*** [paragraph (13) (b)] are:

(a) Entrance surface air kerma (in air, no backscatter) or entrance surface dose (in a specified material, with backscatter) in mGy, for a specific radiographic imaging task. The clinical purpose is defined, but the x-ray equipment, technique factors, and image quality criteria may vary among facilities;
(b) Dose length product (DLP) in mGy cm for a given type of computed tomography (CT) examination that has a well-defined anatomical region of clinical study (e.g. routine abdominal CT scan), with specified clinical objective, image quality criteria

and technical factors. The x-ray equipment (i.e., the CT system) may vary among facilities; and

(c) Dose area product (DAP) in mGy cm^2 for a specific fluoroscopic examination. The clinical purpose is clearly defined, but the type of equipment, technique factors and patient characteristics may differ within or among facilities. The relative tissue dose distribution is expected to be minimally variable, such that a proportional change in DAP corresponds to a nearly proportional change in absorbed dose for each of the irradiated tissues.

(18) The term ***specified medical imaging protocol*** refers to a clinical protocol with a fully defined set of specifications that is followed, or serves as a nominal baseline, at a single facility (or several allied facilities), e.g. a protocol for a PA chest radiograph that specifies the clinical purpose, the technical conduct of the procedure, the image quality criteria, any unique patient characteristics, and other appropriate factors. Examples of quantities and their application to promote attainment of an optimum range of values for a ***specified medical imaging protocol*** [paragraph (13) (c)] are:

(a) Milliampere second (mAs) for a specific CT protocol. The clinical purpose, type of equipment, technique factors and patient characteristics are defined.

(b) Administered activity (A) in MBq for a specific imaging protocol for single photon emission computed tomography (SPEC). The clinical purpose, type of equipment, technique factors and patient characteristics are defined.

Note on Fluoroscopically-guided Interventional Procedures

(19) For fluoroscopically-guided interventional procedures, diagnostic reference levels, in principle, could be used to promote the management of patient doses with regard to avoiding unnecessary stochastic radiation risks. However, the observed distribution of patient doses is very wide, even for a specified protocol, because the duration and complexity of the fluoroscopic exposure for each conduct of a procedure is strongly dependent on the individual clinical circumstances. A potential approach is to take into consideration not only the usual clinical and technical factors, but also the relative "complexity" of the procedure. More than one quantity (i.e. multiple diagnostic reference levels) may be needed to evaluate patient dose and stochastic risk adequately.

(20) Diagnostic reference levels are not applicable to the management of deterministic radiation risks (i.e. radiation-induced skin injuries) from fluoroscopically-guided interventional procedures. In this case, the objective is to avoid deterministic effects in individual patients undergoing justified, but long and complex procedures. The need here is to monitor in real time whether the threshold doses for deterministic effects are being approached or exceeded for the actual procedure as conducted on a particular patient. The relevant risk quantity is absorbed dose in the skin at the site of maximum cumulative skin dose. A helpful approach is to select values for maximum cumulative absorbed dose in the skin at which various clinical actions regarding the patient's record or care (related to potential radiation-induced skin injuries) are taken (ICRP, 2000). Then, during actual procedures, appropriate quantities that can help indicate the maximum cumulative absorbed dose in the skin are monitored.

Local Flexibility in Setting Diagnostic Reference Levels

(21) Diagnostic reference levels should be used by authorized bodies to help manage the radiation dose to patients so that the dose is commensurate with the clinical purpose.

(22) The concept of a diagnostic reference level permits flexibility in the choice of quantities, numerical values, and technical or clinical specifications, in order to allow authorized bodies to meet the objectives relevant to their circumstances. The guiding principles for setting a diagnostic reference level (DRL) are:

(a) The regional, national or local objective is clearly defined, including the degree of specification of clinical and technical conditions for the medical imaging task;
(b) The selected value of the DRL is based on relevant regional, national or local data;
(c) The quantity used for the DRL can be obtained in a practical way;
(d) The quantity used for the DRL is a suitable measure of the relative change in patient tissue doses and, therefore, of the relative change in patient risk for the given medical imaging task; and
(e) The manner in which the DRL is to be applied in practice is clearly illustrated.

(23) Committee 3 encourages authorized bodies to set diagnostic reference levels that best meet their specific needs and that are consistent for the regional, national or local area to which they apply.

References

IAEA (2001). International Conference (IAEA/EC/PAHO/WHO). Developing and Using Dose Guidance (Reference) Levels in Radiology and Nuclear Medicine Examinations. Contributed papers, pages 403-487, in Radiological Protection of Patients in Diagnostic and Interventional Radiology, Nuclear Medicine and Radiotherapy (International Atomic Energy Agency, Vienna).

ICRP (1991). International Commission on Radiological Protection. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Annals of the ICRP 21, No. 1-3 (Pergamon Press, Oxford)

ICRP (1996). International Commission on Radiological Protection. Radiological Protection and Safety in Medicine. ICRP Publication 73. Annals of the ICRP 26, No. 2 (Pergamon Press, Oxford)

ICRP (2000). International Commission on Radiological Protection. Avoidance of Radiation Injuries from Interventional Procedures. ICRP Publication 85. Annals of the ICRP 30, No. 2 (Pergamon Press, Oxford)

Table 1. Approaches to Reference Levels

Document	Term Used	Exam Type: Measured Quantity	Selection	Purpose
ICRP 73 (1996) Radiological Protection and Safety in Medicine. ICRP Publication 73. International Commission on Radiological Protection (1996)	**diagnostic reference level**	diagnostic radiology and nuclear medicine (common exams & broadly defined types of equipment); easily measured quantity (for radiology, absorbed dose in air or in tissue-equivalent material at surface of a simple standard phantom or representative patient; for nuclear medicine, administered activity)	professional medical bodies; percentile point on observed distribution for patients; specific to country or region	advisory: form of investigation level, identify unusually high levels; in principle, lower level also; not for regulatory or commercial purposes; not a dose constraint; not linked to limits or constraints
CRCPD (1988) (General, U.S.) Average Patient Exposure Guides. CRCPD Publication 88-5. Conference of Radiation Control Program Directors, Inc. (1988) [see Note 1]	**patient exposure guides**	medical, mammography and dental: ESE in mR; measurements in air, no phantom	derived from inspection of data from US surveys; reflect "state of current practice"	non-regulatory: tied to specific technique factors: patient thickness, SID, grid, film speed, kVp (for dental)
IPSM (1992) (General, U.K.) National Protocol for Patient Dose Measurements in Diagnostic Radiology. Dosimetry Working Party, Institute of Physical Sciences in Medicine (1992)	**reference dose levels**	radiographs: ESD in mGy exams: DAP in Gy cm2 [average for at least 10 adult patients, avoid extremes in physique (70 ± 10 kg)]	rounded 3rd quartile values from U.K. surveys	p.15: "… could be construed as dose constraints that have been set at the national level"; "achievement of doses below reference levels should not be construed as an indication of satisfactory or optimum performance"
IAEA (1996) (BSS) International Basic Safety Standards Protection against Ionizing Radiation and for the Safety of Radiation Sources. Safety Series No. 115. International Atomic Energy Agency (1996)	**guidance levels**	radiographs: ESD in mGy (for film-screen combinations with relative speed 200; reduce by factor of 2 to 3 for film speed 400-600) computed tomography: MSAD in mGy (on axis of rotation, water phantoms for head and body) mammography: AGD in mGy; 4.5 cm, 50/50; Mo-Mo fluoroscopy: ESD rate in mGy per minute nuclear medicine: A in MBq	derived from wide-scale surveys for typical adults	corrective actions if doses fall substantially below levels with no useful information or medical benefit … or if doses exceed levels

Note 1: CRCPD (1988) was preceded by earlier U.S. guidance (FR, 1978). CRCPD (1988) superceded an earlier document (CRCPD, 1980) and has since been superceded by a later document (CRCPD, 1992). [FR (1998). Federal Register, Volume 43, No. 22. Radiation Protection Guidance to Federal Agencies for Diagnostic X Rays.] [CRCPD (1980). Patient Exposure Guides for Diagnostic X Ray.] [CRCPD (1992). Average Patient Exposure Guides. CRCPD Publication 92-4.]

Table 1. Approaches to Reference Levels (continued)

Document	Term Used	Exam Type: Measured Quantity	Selection	Purpose
NRPB (1999) (General, U.K.) Guidelines on Patient Dose to Promote Optimisation of Protection for Diagnostic Medical Exposures. Documents of the NRPB, Vol 10, No 1. National Radiological Protection Board (1999) **Also, ARSAC (1998) (Nuclear Medicine, U.K.)** Notes for Guidance on the Clinical Administration of Radiopharmaceuticals and Use of Sealed Radioactive Substances. Administration of Radioactive Substances Advisory Committee (ARSAC), Department of Health (U.K.) (1998)	**suspension level** (screening mammography)**; reference doses; achievable doses;** and **diagnostic reference levels** (DRL, nuclear medicine)	radiographs: ESD; mGy for adult, uGy for pediatric mammography: MGD in mGy for standard breast model dental radiographs: intraoral, PED in mGy; panoramic, DWP in mGy mm fluoroscopic exams: DAP in mGy cm2 computed tomography: single slices, CTDIw in mGy; exams, DLP in mGy cm nuclear medicine: A in MBq	**reference doses** 3rd quartile distribution of mean values, U.K. survey **achievable doses** values achievable by standard means in widespread use: radiographs, mean value for facilities meeting European recommendations mammography, value based on U.K. survey of good technique **diagnostic reference levels** guidance for practitioners in U.K.	**suspension level** (screening mammography) if exceeded, subject to immediate review of practice **reference doses** investigation levels: threshold for the internal investigation of potentially poor practice within a department; not a formal regulatory tool **achievable doses** supplemental to reference doses; promote optimzation of practice **diagnostic reference levels (nuclear medicine)** pragmatic values based on accepted customs & practice; thresholds above which special justification is required; required by certificate issued by regulatory authority (previously, maximum usual activities, MUA)
EC (1999a) (General) Guidance on Diagnostic Reference Levels (DRLs) for Medical Exposures. Radiation Protection 109. Directorate-General, Environment, Nuclear Safety and Civil Protection. European Commission (1999) **Also, Nordic (1996) (General); SSK (2000) (Nuclear Medicine)** [see Note 2]	**diagnostic reference levels**	radiographs: ESD in mGy fluoroscopic exams: DAP in mGy cm2 [average for at least 10 adults; avoid extremes in physique (70±3 kg)] mammography: ESD in mGy for a standard phantom nuclear medicine: A in MBq	radiography: 3rd quartile values from European surveys nuclear medicine: administered activity necessary for a good image during a standard procedure	**x-ray examinations:** groups of standard-sized patients or phantoms, broadly defined types of equipment; levels expected not to be exceeded when good and normal practice is applied; when consistently exceeded, review procedures and equipment **nuclear medicine:** "optimum" national values; for children, a fraction of adult values

Note 2: [Nordic (1996). Nordic Guidance Levels for Patient Doses in Diagnostic Radiology. Report on Nordic Radiation Protection Co-operation No. 5 (Denmark, Finland, Iceland, Norway and Sweden)] [SSK (2000). Diagnostic Reference Levels in Nuclear Medicine. Recommendation of the Radiation Protection Commission (Session 167) (Germany)]

Table 1. Approaches to Reference Levels (continued)

Document	Term Used	Exam Type: Measured Quantity	Selection	Purpose
European Commission Documents with Same Approach				
EC (1990) (General) Working Document on Quality Criteria for Diagnostic Radiographic Images. CEC XII/173/90. Commission of European Communities (1990) **EC (1993) (Mammo)** European Guidance for Quality Assurance in Mammography Screening. EUR 14821. European Commission (1993) **EC (1996a) (General)** European Guidelines of Quality Criteria for Diagnostic Radiographic Images. Eur 16260 EN. European Commission (June 1996) **EC (1996b) (Pediatric)** European Guidelines on Quality Criteria for diagnostic Images in Paediatrics. EUR 16261 EN. European Commission (July 1996) **EC (1999b) (CT)** European Guidance on Quality Criteria for Computed Tomography. EUR 16262. European Commission (May 1999)	**reference dose value** (criteria for radiation dose to the patient)	radiographs: ESD; mGy for adult, uGy for pediatric mammography: 4.5 cm; grid not specified; EC (1990) mammography: ESD in mGy; 50 mm breast = 45 mm PMMA; OD = 1.0; EC (1993) mammography: ESD in mGy; 5 cm, Mo target, Mo/Al filter; EC (1996a) computed tomography: single slices, CTDIw in mGy; exams, DLP in mGy cm (head phantom, 16-cm diameter; body phantom, 32-cm diameter; PMMA) adults: use sample of 10 patients near standard size, 60-80 kg; pediatric: use sample of 10 patients, 4-6 years old, 15-25 kg	3rd quartile values from European surveys	investigation levels (investigate reason for exceeding): tied to diagnostic requirements, image criteria and good radiographic technique

Table 1. Approaches to Reference Levels (continued)

Document	Term Used	Exam Type: Measured Quantity	Selection	Purpose
EC (1996c) (Mammo) European Protocol on Dosimetry in Mammography. EUR 16263 EN. European Commission (June 1996)	**limiting value**	mammography: ESAK & AGD in mGy; 45 mm PMMA; OD = 1.0	conversion from EC (1993) value for ESD	p. 49: "dose constraints"; "used to cover different terms like limiting values, reference levels, action levels, etc."
FDA (1997) (Mammo, U.S.) Quality Mammography Standards; Correction; Final Rule. Federal Register, Volume 62, Number 217, 60613-60632. Food and Drug Administration (November 10, 1997) … at [www.fda.gov/cdrh/fr/fr1110af.html]	**dose limit**	mammography: AGD in mGy, craniocaudal view; using accepted FDA phantom; for all systems; for technique factors and conditions used clinically for a standard breast (4.2 cm; 50/50)	adapted from American College of Radiology quality control manual	regulatory requirement (shall not exceed): for screening mammography; quality assurance test, perform at least annually; part of extensive equipment quality assurance requirements (provision effective April 1999)
AAPM (1999) (General, U.S.) Reference Values-Applications and Impact in Radiology. American Association of Physicists in Medicine Task Group (November 1999 Draft)	**reference value**	radiographs: ESAK in mGy (ESE in mR) ; measurements in air, no phantom computed tomography: CTDI in mGy, in phantom with backscatter fluoroscopy: ESAK rate in mGy per minute (ESE in mR per minute))	derived from 75th or 80th percentile of U.S. survey data	non-regulatory: to assist medical professionals in evaluating exposure levels; if exceeded, facility investigates reason; reduce, if possible without sacrificing image quality
NRPB (2000) (Pediatric) Reference Doses and Patient Size in Paediatric Radiology. NRPB-R318. National Radiological Protection Board (November 2000)	**reference dose**	radiographs: ESD in uGy complete examinations: DAP in mGy cm2 pediatric ages: neonate, 1, 5, 10 and 15 years [use measured values, for individual children, normalized to standard size of nearest pediatric age]	rounded values of third quartile European surveys	provisional reference doses: useful and practical way of promoting optimization of patient protection; referenced to concepts in ICRP publications and the EC Medical Exposure Directive

List of Symbols and Acronyms:

ESD - entrance surface dose (with backscatter)
ESD rate - entrance surface dose rate (with backscatter)
ESAK - entrance surface air kerma (free-in-air)
PED - patient entrance dose (free-in-air)
ESE - entrance skin exposure (free-in-air)
MSAD - multiple scan average dose
CTDI - computed tomography dose index (U.S.)
CTDIw - weighted computed tomography dose index (EC)
OD - optical density
DLP - dose length product
DAP - dose area product
DWP - dose width product
AGD - average glandular dose
MGD - mean glandular dose
A - administered activity
MUA - maximum usual activity
DRL - diagnostic reference level

Table 2. Listing of Reference Levels

Medical Imaging Task	(General, U.S.) CRCPD 1988	(General, U.K.) IPSM 1992	(BSS) IAEA 1996	(General) EC 1990,1996a, 1999a	(General, U.S.) AAPM 1999	(General) NRPB 1999
Radiographs [values are ESD in mGy, except as noted for CRCPD, AAPM and NRPB]						
[NOTE: CRCPD entries were converted from ESE in mR (x 0.00876) to ESAK in mGy]						
Dental Panoramic						65
Dental (periapical)			7			[DWP in mGy mm]
AP Dental	[ESAK in mGy]		5		[ESAK in mGy]	
Dental Cephalometric	0,3				0,25	
Dental Intraoral (bitewing)	function of kVp & speed				2.3 (70 kVp,E)	mandibular molar
(ex: 70 kVp and E speed)	2.1 to 3.1 (range)				3.5 (70 kVp,D)	4, **1.8** [PED,mGy]
PA or AP Skull		5	5	5		5, **1.5**
LAT Skull	1.3, 0.6	3	3	3		3, **1**
AP Cervical Spine	1.2, 0.8				1,25	
PA Chest	0.1, 0.04 no grid	0,3	0,4	0,3	0,25	0,3
	0.2, 0.1 grid					
LAT Chest		1,5	1,5	1,5		1,5
AP Thoracic Spine			7			
LAT Thoracic Spine			20			
AP Full Spine	2.3, 1.3					
AP Abdomen	4.3, 2.6	10	10		4,5	10, **6**
AP or PA Lumbar Spine	3.9, 3.1	10	10	10	5	10, **5**
LAT Lumbar Spine	[two film speeds:	30	30	30		30, **12**
LAT Lumbar Spine	200, then 400]	40	40	40		40, **24**
(lumbo-sacral joint)						
AP Pelvis		10	10	10		10, **4**
AP Hip Joint			10			[reference dose,
AP Urinary Tract				10		then **achievable**
(plain film or before contrast)						**dose**]
AP Urinary Tract (after contrast)				10		

Pediatric Radiographs [values are ESD in uGy, except for MCU exam]	(Pediatric) NRPB 2000					(Pediatric) EC 1996b,1999a	(General) NRPB 1999
	0-yr	1-yr	5-yr	10-yr	15-yr		
AP & PA Chest		50	70	120		100 (5-yr old)	100 (5-yr old)
LAT Chest						200 (5-yr old)	200 (5-yr old)
AP Chest Newborns	50					80 (newborn)	80 (newborn)
PA or AP Skull		800	1100	1100	1100	1500 (5-yr old)	1500 (5-yr old)
LAT Skull		500	800	800	800	1000 (5-yr old)	1000 (5-yr old)
AP Pelvis (infants)						200 (infant)	200 (infant)
AP Pelvis (older children)		500	600	700	2000	900 (5-yr old)	900 (5-yr old)
AP or PA Abdomen (with vertical beam)		400	500	800	1200	1000 (5-yr old)	1000 (5-yr old)
MCU exam **(Note: DAP in mGy cm2)**	600	900	1200	2400			

[NOTE: quality criteria, but not reference levels also given for the following pediatric radiographs in EC (1996b)]

PA or AP Full Spine	Micturating Cystourethrography	AP or PA Urinary Tract
PA or AP Segmental Spine	AP or PA Urinary Tract	(after contrast)
LAT Segmental Spine	(without or before contrast)	

Table 2. Listing of Reference Levels (continued)

Medical Imaging Task	(General, U.K.) IPSM 1992	(BSS) IAEA 1996	(CT) EC 1999b	(General) NRPB 1999	(General) EC 1999a	(General, U.S.) AAPM 1999
Fluoroscopy [values are in mGy per minute]						
Normal Mode		25				(mode not given)
High-level Mode		100				65
		[ESD rate]				[ESAK rate]
Examinations [values are DAP in Gy cm2]						
Lumbar Spine	15			15	nv 10	
Barium Enema	60			60	60 50	
Barium Meal	25			25	25 25	
Intervenous Urography	40			40		
Abdomen	8			8		
Pelvis	5			5	nv 4	
Chest					nv 1	
Urography					40 20	
					[values cited: U.K.; then Nordic]	
					[nv, no value]	
Computed Tomography [values are MSAD in mGy]						
CT Head		50				
CT Lumbar Spine		35				
CT Abdomen		25				
Computed Tomography [values are in mGy (CTDIw, CTDI) or mGy cm (DLP), as noted]						
			[CTDIw (slice), then DLP (exam)]			[CTDI (exam)]
Routine Head			60, 1050	60, 1050		60 (head)
Routine Chest			30, 650	30, 650		40 (all body sites)
Routine Abdomen			35, 780	35, 800		
Routine Pelvis			35, 570	35, 600		
Face & Sinuses			35, 360			
Vertebral Trauma			70, 460			
HRCT of Lung			35, 280			
Liver and Spleen			35, 900			
Osseous Pelvis			25, 520			

[NOTE: quality criteria, but not reference levels also given for the following CT procedures in EC 1999b]

Skull Base	Pharynx	Kidneys
Petrous Bone	Larynx	Pancreas
Orbits	Lumbar Spine, Discal Hernia	Adrenal Glands
Sella and Hypophysis	Spinal Cord	Osseous Shoulder
Salivary Glands (parotid and submandibular)	Chest, Mediastinal Vessels	

Table 2. Listing of Reference Levels (continued)

Medical Imaging Task	(General, U.S.) CRCPD 1988	(General) EC 1990,1996a, 1999a	(BSS) IAEA 1996	(General) NRPB 1999 [+ARSAC 1998]	(Mammo) EC 1993,1996c	(Mammo, U.S.) FDA 1997
Mammography [values are ESD, ESAK, AGD or MGD in mGy, as noted]						
[NOTE: CRCPD entries were converted from ESE in mR (nominal BF=1.1) and AGD in mrad]						
LAT Breast		10 (1999a)				
MLO Breast		7 (1990), 10 (1996a;1999a)		***3, 2, 1.5**		
CC Breast		7 (1990), 10 (1999a)		***3 ,2, 1.5**	12, 11, **2.3**	**[3]**
screen-film (no grid)	3.3, **0.6**		**1**			
screen-film (grid)	6.7, **1.4**	10 (1996a)	**3**			
Xerox (positive)	8.6, **4.0**					
Xerox (negative)	6.5, **3.4**					
	[ESD, then **AGD**]	[ESD]	**[AGD]**	**[MGD]** [***suspension level, reference dose,** then **achievable dose**]	[ESD, ESAK, **AGD**]	**[AGD]** [**dose limit**]

Nuclear Medicine [values are A in MBq, for adults] … Examples

	(General) EC 1999a		(BSS) IAEA 1996	(Nuclear Medicine) ARSAC 1998	SSK 2000
Bone Imaging [MDP/HDP]	400	600	600	600	750
Liver/Spleen Studies [colloid]	80	80	80	80	no value
Liver/Spleen Studies [IDA]	40	150	150	150	150
Lung Perfusion Imaging [MAA]	100	100	100	100	200
Renal Imaging [DMSA]	80	80	160	80	70
Dynamic Renal Scanning [DTPA]	80	300	350	300	150
Dynamic Renal Scanning [MAG3]	40	100	100	100	200
[all technetium-99m]	[Netherlands, U.K.; DRLs]		[guidance levels]	[DRLs (MUAs)]	[DRLs]

[NOTE: EC 1999a gives values for several other countries. EC 1999a and SSK 2000 give a set of values for children.]

List of Symbols and Acronyms:

ESD - entrance surface dose (includes backscatter)
ESD rate - entrance surface dose rate (includes backscatter)
ESAK - entrance surface air kerma (free-in-air)
PED - patient entrance dose (free-in-air)
ESE - entrance skin exposure (free-in-air)
MSAD - multiple scan average dose
CTDI - computed tomography dose index (U.S.)
CTDIw - weighted computed tomography dose index (EC)
DLP - dose length product
DAP - dose area product
DWP - dose width product
AGD - average glandular dose
MGD - mean glandular dose
A - administered activity
MUA - maximum usual activity
AP - anterioposterior
PA - posterioanterior
LAT - lateral
CT - computed tomography
HRCT - high resolution computed tomography
MLO - mediolateral oblique
CC - craniocaudal
BF - backscatter factor
IDA - iminodiacetic acid
MAA- macroaggregated albumin
DMSA - dimercaptosuccinic acid
DTPA - diethylenetriaminepentacetic acid
MAG3 - mercaptoacetyltriglycine
DRL - diagnostic reference level
MDP - methylene diphosphonate
HDP - hydroxymethylene diphosphonate
MCU - micturating cystourethrography