



Using diagnostic reference levels to evaluate the improvement of patient dose optimisation and the influence of recent technologies in radiography and computed tomography



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ABSTRACT

Objectives: Twelve years since the implementation of Diagnostic Reference Levels (DRL) process in France, the Nuclear Safety and Radiation Protection French Institute (IRSN) presents its latest analyses performed on the most recent national data.

Methods: Statutorily, each year, medical imaging departments must perform patient exposure evaluation from their clinical practice for at least 2 types of radiographic and computed tomography (CT) examinations freely chosen in the regulatory list. The samples of dosimetric data used for the evaluations must be sent to IRSN for national assessment using a dedicated and secured web portal. The analyses of collected data for radiography and CT allow IRSN to estimate the representativeness of current DRLs in terms of target practices and examinations, dosimetric quantities and numerical values. Technical data are transmitted, such as detector type in radiography or commissioning date of CT, and are included in some complementary analyses in order to evaluate their influence on patient exposure.

Results: Since 2004 the involvement of professionals in the DRL process has highly increased in CT (about 80% in 2015) but remains quite weak in radiography (almost 30%). Analyses show some discordance between regulation references and clinical practice leading to clinical doses data which are 40% lower than DRLs in 2015. As a consequence, the list of examinations types and some numerical values should be updated in the regulation.

Focused analyses show a significant patient exposure reduction when digital radiography is used and when CT equipment is under five years old.

Conclusions: Based on these findings, IRSN recommends to update DRL regulation with current and relevant examination lists, dosimetric quantities and numerical values. In addition, this study shows that technology and generation of equipment, such as detector type in radiography or image reconstruction algorithm in CT, take an important place in the dose optimisation process, enabling significant patient exposure reduction when it is associated with protocols optimisation.

1. Introduction

In the field of medical imaging, the radiation protection of the patients is based on the basic principles of practice justification and dose optimization. Once an examination is justified, it must be performed with the most efficient balance between dose reduction and image quality upholding.

Introduced during the early 1990s by the International Commission on Radiological Protection (ICRP), the concept of diagnostic reference level (DRL) [1,2] is currently recognized as an obvious element of the dose optimisation system in many countries. These levels are expected

not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied.

Numerous works about DRLs headed by international institutions and organisations – European Commission (EC) [3,4], ICRP [5], International atomic energy agency (IAEA) [6] – are in progress and results from these studies are expected to be available in the near future.

Initially defined and requested by the European council Directive 97/43 [7], root of the French regulation, the implementation of DRLs is strengthened in the latest European council Directive 2013/59 [8,9].

In France, DRLs were officially introduced in 2004 through a national order [10], setting the types of examinations to be considered,

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with associated DRLs numerical values, and giving the French Institute for Radiological Protection and Nuclear Safety (IRSN) the responsibility of collecting dosimetric data sent by diagnostic radiology, computed tomography (CT) and nuclear medicine departments in order to periodically update the DRLs.

Therefore, IRSN assesses collected data, analyses it and gives recommendations to national authorities in order to update French DRLs according to national results.

The mandatory examinations list and DRLs numerical values were updated in 2011 based on the data analyses and recommendations of IRSN [11].

This paper presents the main results of data analyses for the 2013–2015 period and the follow-up since 2004, for adult patients [12]. Some focused analyses on technological evolutions are presented, and then expected evolutions of DRLs in France are introduced.

2. Materials and methods

2.1. Current settings of DRLs

The current list of examinations and DRLs values is available in the latest DRL order of the 24th October of 2011 [11].

2.1.1. Radiographic DRLs

In radiography, DRLs are set for 12 adult examinations, for a single view. The current reference dosimetric quantities are the entrance surface dose (ESD in mGy) and dose area product (DAP in cGy cm²) with associated DRL values.

2.1.2. Computed tomography DRLs

For computed tomography (CT), DRLs are defined for 5 adult common examinations, and only per sequence. Reference dosimetric quantities chosen for this modality are volume computed tomography dose index (CTDI_{vol} in mGy) and dose length product (DLP in mGy.cm).

2.2. Data collection and analysis

As requested by the regulation, each year, IRSN receives data from diagnostic medical imaging departments including CT rooms, thanks to a web-accessed platform. For each room, at least 2 samples of examination data are transmitted to IRSN. Departments are free to choose the 2 types of examination in the list published in the DRL order. It is recommended, when it is consistent with practice, to choose different types of examination between two following years. Each sample, taken from at least 30 patient examinations, includes dosimetric data (DAP in radiography, CTDI_{vol} and DLP in CT), exposure parameters (tube voltage (kV), tube current time-product (mAs), pitch...) and patient data (age, height, weight). It should be noticed that, since 2011, no selection is required on the weight of adult patient. Between 2004 and 2011, data referred to “standard-sized” patients (60–80 kg).

Radiographic data is represented by more than 85% of DAP values, ESD representing only a few rate of the data, due to the obligation of a DAP calculation or measurement system on every radiographic device in France since 2004. As a consequence, DRLs in terms of ESD are useless and difficult to update. This is the reason why, in this work, only DAP data is analysed for radiography. The quality control of equipment, including dosimetric tests, is mandatory in France. All data is supposed to have been collected on controlled equipment.

Then, data analyses consist in:

- The evaluation of professionals’ compliance to the regulation requests: rate of departments having sent data for each modality,
- Plotting the examination types distribution for each modality,
- Statistical calculations on dosimetric data: number of data (1 data = average value of a sample of at least 30 patients), average patients weight, 75th percentile, median (50th percentile) and

interquartile ratio. The objective of the 75th percentile is to alert professionals on dosimetric exceeding in their practice, due for example to inconsistent protocol or equipment failure. The aim of 50th percentile is to encourage professionals to persevere in a dose optimisation process even if their practice is below DRL value.

- Complementary analyses focused on consistent equipment features which have an influence on patient dose: in radiography, the influence of the detector type has been investigated and in CT the influence of the age of the device has been related to the dosimetric indexes values.

Presented results and statistical indexes values refer to the most recent data, collected during the year 2015, with the objective of displaying a representative and up-to-date view of the current practice. The focused analyses were performed on 2013–2015 data in order to improve the consistency of the results thanks to a significant amount of data. Paediatric practice is not considered in this paper whereas paediatric DRLs are implemented in France. Due to specificities related to data collection difficulties, this field needs a separate analysis and discussion.

3. Results

3.1. Radiography

3.1.1. Routine analyses

The number of diagnostic radiology departments in France is approximately estimated to 5100. In 2015 about 30% of radiology departments complied with the DRL regulatory request of sending data to IRSN. The results of data collection and statistical indexes calculations are shown in the Table 1 for the 11 types of examination listed in the DRL order.

Chest (frontal and lateral), lumbar spine (frontal and lateral), abdomen (frontal) and pelvis (frontal) are the most numerous data. The amount of data collected in 2015 is significant for each type of examination, from 50 (dental panoramic) to 564 rooms (chest PA).

The calculated 75th percentile of 2015 data is lower than the current DRL value for all types of examinations, from –19% (chest PA) to –53% (lateral thoracic spine). The rate of departments which practice is higher than DRL represents less than 10% for all types of examinations. In comparison to the previous report results (2011–2012 data) [13], an overall decrease of the 75th percentile values is observed, from

Table 1
Summary of radiography dose area product (DAP) data analyses, for each examination type and adult patients in 2015.

Examination type	N	Average weight (kg)	DAP (cGy cm ²)			
			Current DRL	75th	50th	
Chest (PA)	564	70.5	25	20.2	14.8	2.14
Chest (LAT)	226	70.8	100	59.8	45.1	1.98
Abdomen	167	70.9	700	374	283	2.15
Pelvis (AP)	460	70.7	700	425	313	1.82
Hip (AP or LAT)	191	71.2	300	149	106	2.01
Cervical spine (AP or LAT)	199	69.6	75	39.0	27.6	2.10
Thoracic spine (AP)	118	69.8	175	108	81	1.70
Thoracic spine (LAT)	55	70.3	275	130	93	2.10
Lumbar spine (AP)	287	70.1	450	282	222	1.82
Lumbar spine (LAT)	149	71.7	800	425	295	2.11
Dental panoramic	50	–	20	13.6	11	2.11

Are presented: number of rooms (N), average weight of patients, current DRL value, 75th percentile value, 50th percentile value and 75th/25th ratio.

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