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PII: S0720-048X(17)30427-8
DOI: https://doi.org/10.1016/j.ejrad.2017.11.002
Reference: EURR 8006

To appear in: *European Journal of Radiology*

Received date: 14-6-2017
Revised date: 26-9-2017
Accepted date: 6-11-2017

Please cite this article as: Roch Patrice, Célier David, Dessaud Cécile, Etard Cécile.Using diagnostic reference levels to evaluate the improvement of patient dose optimisation and the influence of recent technologies in radiography and computed tomography.*European Journal of Radiology* https://doi.org/10.1016/j.ejrad.2017.11.002

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.

Keywords: Patient dose; radiography; CT; optimisation; diagnostic reference levels.

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, 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.

MATERIALS AND METHODS:

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].

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 $cGy.cm^2$) with associated DRL values.

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).

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, 75^{th} percentile, median (50^{th} percentile) and interquartile ratio. The objective of the 75^{th} percentile is to alert professionals on dosimetric exceeding in their practice, due for example to inconsistent protocol or equipment failure. The aim of 50^{th} percentile is to encourage professionals to perseverate 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.

RESULTS:

Radiography

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 -2% (AP thoracic spine) to -29% (lateral thoracic spine), excepted for dental panoramic (+6%). But, the extreme values (-29% and +6%) must be put in perspective with the weak amount of data (about 50), introducing a bias in the evolution quantification.

Focused analysis: influence of the type of detector on the patient exposure

Information provided by radiology departments regarding their equipment features when sending their data allows IRSN to compare data acquired on radiographic films, phosphor plates and flat panel detectors. The figure 1 and the table 2 give, for each type of detector, some information on:

- The amount of collected data: phosphor plates and flat panels detectors are the most used technologies. Radiographic film remains used but in a very low rate,
- The dosimetric statistics (dispersal of the dose values, value of specific 75th percentile): the range of doses is very large whatever the considered detector is. The dose is correlated with the type of detector: the comparison of the DAP 75th percentiles shows that radiographic film and phosphor plate detectors are responsible for respectively 20 and 30% more dose than flat panel detector, respectively.

The table 2 gives some information for 3 common examinations (chest PA, pelvis AP and lumbar spine AP) and the figure 1 is focused on the chest PA examination.

Computed tomography

Routine analysis

The number of CT equipment in France is estimated about 1100, representing 16.6 devices per million population, to be compared to the European Union value of 20.7 (min: 7.9; max: 36.1) [14]. In 2015, data were received from almost 80% of the overall number of CT equipment. The results of data collection and statistical indexes values are shown in the tables 3 and 4 for the 5 types of examination listed in the DRL order.

The ranking of DRL data from the most numerous to the lower one is: brain, chest, abdomen-pelvis (AP), lumbar spine and chest-abdomen-pelvis (CAP). The amount of data collected during 2015 is significant for each type of examination, from 117 (CAP) to 369 rooms (brain), representing almost 30% of the overall number of CT, excepted for CAP examination which is shared between CAP alone and CA plus AP acquisitions.

The calculated 75th percentile of the 2015 $CTDI_{vol}$ data is lower than the current DRL value for all types of examinations, from -25% (AP) to -44% (CAP). The calculated 75th percentile of the 2015 DLP data is lower than the current DRL value for 4 of 5 types of examinations, from -20% (AP) to -28% (chest). The 75th percentile DLP value is higher than the DRL for the lumbar spine examination (+9%). The rate of departments which doses are higher than DRL represents less than 2% for all types of examinations in terms of $CTDI_{vol}$ and less than 6% considering DLP, excepted for the lumbar spine (about 35%). Comparing to the previous report results [15], the 75th percentiles have decreased for all types of examinations, from -8% (DLP, lumbar spine) to -21% ($CTDI_{vol}$, CAP) [13].

Focused analysis: influence of CT generation on the patient exposure

Information provided by departments on their equipment when sending their data allows IRSN to perform analyses taking into account the commissioning date of the CT scanners. The figure 2 shows, for the example of AP examination which is representative of the whole examinations, as a function of CT commissioning date:

- The rate of CT devices: about 40% of CT devices are older than 5 years,

- The calculated 75th percentile value of DLP which appears to be correlated to the CT age. The older the CT is, the higher the DLP is. The 75th percentile is higher than the overall value of the 75th percentile for much than 5 years old CTs, and lower than current DRL for others. The 75th percentile DLP of oldest CTs is about 35% higher than most recent CTs DLPs.

DISCUSSION:

Regarding the national dose data knowledge and the representativeness of current clinical practices, twelve years after its implementation, the DRL process in France appears to be successful. This is due to the significant amount of collected dosimetric data and the correlation of DRL data distribution considering examination types and the frequency of examinations performed in France [16].

Concerning the results, at a national level, the evolution of dosimetric indexes since 2004 shows a continuous decrease of patient exposure for all the types of examinations, for both radiography and CT. Between each periodical assessment, every 2 or 3 years, patients “doses” decreased of about 15% in average in radiology and CT leading to 75th percentile values which are, in average for 2015, about 40% lower than DRLs in radiology, and almost 35% in CT. As a consequence, a national DRLs update is essential in order to maintain an optimisation promotion to the professionals through DRL process and IRSN proposes updated DRLs values. Some additional types of CT examinations (chest-abdomen, heart and sinus) are proposed in order to take into account the most frequent performed examinations in French radiology departments. The corresponding proposed DRL values of these 3 types of examinations have been set according to the results of IRSN targeted surveys [17, 18]. DRLs propositions are set as the 75th percentiles of data distributions.

It should be noticed that, despite of the abolition of a weight criteria for the selection of patient data, an average weight of about 70kg is observed from collected data. It shows the importance of collecting patient weight in order to evaluate the characteristics of the population in the sample of DRL data and, as a consequence, to relate dosimetric and morphological values. But, this finding highlights that, selecting patients included in the sample of DRL data according to a weight range (60-80kg) as it was requested in the past doesn’t benefit to the quality of DRLs. The collection of data without weight criteria lead to the same result than selecting “standard sized” patients. So, this constraint which

increases time for data collection in the case of examinations which are not frequently performed in some departments is not justified in France.

These results also encourage the definition of an "optimisation" index (50^{th} percentile) complementarily to the 75^{th} percentile which can be considered as an alert warning on inappropriate practice, from a dosimetric point of view (table 5 and 6). This additional index would also be coherent with the recent recommendations of ICRP for the definition of an "achievable dose" value (AD) [5].

The updated DRL propositions have been compared with the most recent DRL values from some other countries (tables 7 and 8) [19-29].

Considering radiography, although dosimetric indexes values have been continuously decreasing since 2004, French 75^{th} percentiles are higher than DRLs values of other countries for 8 of the 11 types of examination, equal to the higher value of DRLs values of other countries for 2 of the 11 and between the lower and the higher DRLs values for only 1 type of examination.

In the case of the CT, French 75^{th} percentiles of $CTDI_{vol}$ and DLP are lower than or equal to the lowest DRL values of other countries for almost all examination types.

The comparison of DRLs among different countries must take into account the potential differences of methodology. The method of data collection can be different: some countries (UK, Switzerland for example) collect their data thanks to surveys conducted in a consistent sample of hospitals, others collect data from all medical imaging centres at a national level (Belgium, France for example). The participation to surveys is sometimes volontary (UK) or mandatory (Belgium, France and Germany). The focused or nationwide collection doesn't seem to be a factor of influence on the results. The mandatory aspect of participation could be more influent because volunteers might feel more concerned by radiation protection and consequently more performant in radiation dose optimisation. In radiography, methodological differences cannot explain the gap between different countries. The most probable reason is the maturation of the process of optimisation between the countries and the example of UK shows the effect of the process age on optimisation efficiency.

In CT, some additional factors induce variability in DRL values. CT DRLs are often defined for anatomical regions (head, chest, abdomen, pelvis…) without consideration of the clinical purpose. But, as mentioned by ICRP in its future recommendations, different examinations of the same

anatomical region need variable image quality/amount of radiation if the clinical objective is different [5]. UK has introduced the mention of the clinical indication in DRLs but it is not the same for many of other countries. This can explain why the DLP value of UK DRL for chest CT (lung cancer indication) is the higher one, some of the other countries having probably mixed different indications in the same DRL [20]. It should be noticed that the question of hanging DRLs to clinical indications can be considered as the challenge of the next years [4, 30].

In France, differences of the international positioning between radiography and CT could be explained by:

- A distribution of radiographic practice on different medical categories (radiologists, rheumatologists, dentists, pneumologists, occupational medical doctors…) who have an heterogeneous knowledge of radiation protection, whereas CT is only performed by radiologists who are more sensitive to radiation protection questions than the non-specialists of radiology,
- A radiation protection issue which is less felt in radiography because of the low level of exposition,
- Despite of the obligation, in France, of medical physicists presence in medical imaging departments, a lack of these professionals in radiography departments [31],
- More constrained regulation frame and Authority control follow-up in CT.

As a consequence, this comparison to international data shows that optimisation of patients radiation exposure can be improved in radiography and has already been implemented with efficiency in CT practice.

Performing complementary analyses taking into account some technical features of devices shows that the decrease of doses indexes values depend on the generation and the type of technology of the medical imaging systems. In radiography, as expected from previous surveys [32], when flat panels are used instead of radiographic film and phosphor plates, a significant decrease of patient exposure is observed. This data also highlights the rate of use of the different types of detectors, showing that flat panel and phosphor plates are the most frequent devices and that radiographic films have almost disappeared from radiology departments. But, despite of this encouraging assessment, patient exposure appears to be higher in France than in other comparable countries.

In CT, the plotting of dose data as a function of the commissioning date of the CT device reveals that the older the CT is, the higher radiation exposure of patients is. It can be supposed that recent CT equipment have dose reduction features such as iterative reconstruction, tube current modulation and advanced detector technologies which allow professionals to optimise radiation dose to the patients as it has already been demonstrated [33].

These two examples bring out that patient dose optimisation is strongly linked to the modernity of medical imaging devices, the most recent ones offering the larger possibilities of dose reduction maintaining an efficient image quality.

It should be noticed that these results are also an evidence of the implementation of optimisation process in participating radiology departments because flat panels in radiography or dose reduction tools in CT (i.e. iterative reconstruction, tube current modulation…) need protocols review to be efficient in terms of dose optimisation.

The question of the use of DRL data collection as a part of an optimisation process in the participating departments remains difficult to evaluate due to a lack of evidence of the data analysis. At a department scale, the efficiency of the DRL process on the optimisation of patient radiation exposure is difficult to objectify because it necessitate to compare data from same types of examination performed on the same rooms in a consistent delay. As professionals are encouraged to evaluate different types of examination each year, the follow-up of the practice evolution is problematic. The anteriority of data since 2004 allows IRSN to compare data for a type of examination performed twice on a specific room and to evaluate the level of optimisation. Some preliminary analyses have been investigated, showing a rather good influence of DRL on the clinical practice. This work will be developed and published in a close future.

The propositions of DRL updates concern dose indexes values for single view in radiography and per sequence in CT. The opportunity of including DRLs for complete examinations in the future regulation has been evaluated. In radiology, the lack of data concerning complete examinations does not allow IRSN to formulate proposals. A specific survey is necessary to collect consistent dosimetric data including fluoroscopy and multiple views related to different types of examination.

In CT, the number of sequences is strongly dependant of the clinical indication of the examination. For the moment, DRL are only set by anatomical region without any consideration of the clinical purpose. They are a based on a mix of heterogeneous examinations of a similar anatomical region but with very various settings of acquisition parameters per sequence. The concept of CT DRLs for complete examinations should necessarily include the introduction of clinical indications. As a consequence, specific surveys need to be implemented in order to correlate main clinical indications and the number of recommended sequences that should be performed.

In the future, DRL implementation for complete examination will be a priority which has some chance to be reached as some work is currently in progress in France and a project will nearly be launched in Europe [4] in order to identify and set DRLs as a function of clinical indication in CT.

Finally, the pooling of the data based on the median of the distributions have been introduced for the first time in the DRL update proposals in order to be consistent with current and expected international recommendations [3, 5, 6].

CONCLUSION:

Implemented in France twelve years ago, the dosimetric data collection in the frame of regulatory DRL process allowed IRSN to publish its fifth report presenting the analysis of data collected from 2013 to 2015 and providing recommendations in order to update regulatory DRL texts.

From a methodological point of view, the French DRL process is efficient for the collection of national data related to the types of examination listed in the regulation, with a large amount of available and up-to-date data. Regarding professionals involvement in the process, an uncertainty remains on the role of DRLs in dose optimisation in the radiology departments, especially in conventional radiology.

From a dosimetric point of view, the analyses of the most recent data shows a continuous decrease of dose indexes in conventional radiology and CT, allowing authorities to reduce the current DRL values. Technologic evolutions of radiology and CT devices take an important part in this continuous reduction of patient dose and the impact of the type of detector and the generation of device can be

noticed. This significates that professionals have adapted their practice in order to make patient benefit from the dose reduction opportunities offered by such technologies.

Taking into account additional surveys results for currently frequent examinations not listed in the current regulation, IRSN proposes DRLs for three new types of CT examinations.

In the future, the challenge of DRLs update will be to introduce DRLs for complete examinations, especially in CT, related to clinical indication.

Conflicts of interest: none

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Figure 1: Distribution of the average DAP per room as a function of the detector type (analogic film, phosphor plate, flat panel) for chest PA radiography during the 2013-2015 period.

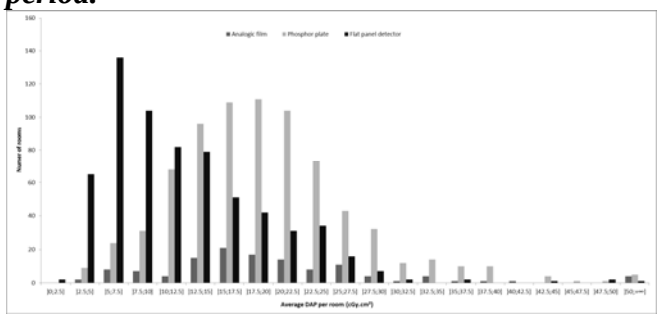

Figure 2: CT commissioning date influence on the Dose length product (DLP) 75th percentile considering the examination of abdomen-pelvis.
Percentages into the graph bars are related to the rate of CTs for each commissioning year. The dark horizontal line represents the 2015 75th percentile of all CTs.

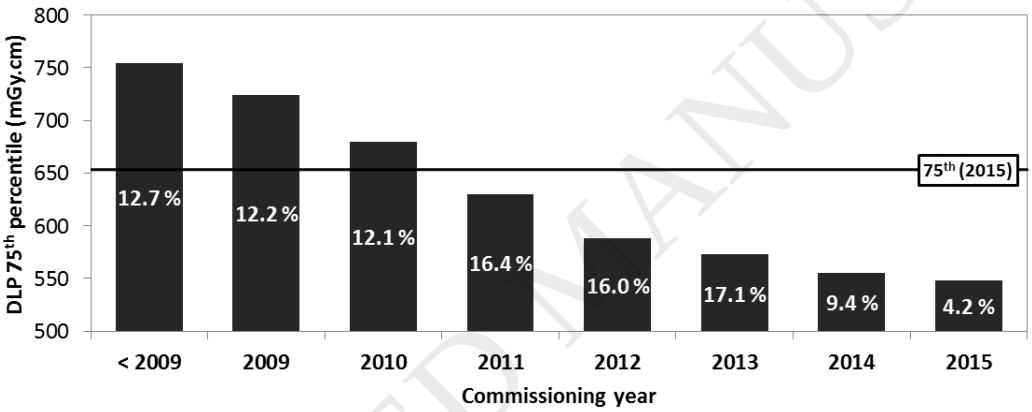

Table 1: Summary of radiography Dose area product (DAP) data analyses, for each examination type and adult patients in 2015.
Are presented: number of rooms (N), average weight of patients, current DRL value, 75th percentile value, 50th percentile value and 75th/25th ratio.

Examination type	**N 2015**	**Average weight (kg)**	**DAP (cGy.cm²)**			**75th/25th**
			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

Table 2: Influence of the detector type on the patient radiation exposure represented by the 75th percentile values of the DAP (DAP_{75} in cGy.cm^2) for the 3 three most performed examinations and the 2013-2015 period.

Examination type	**Chest (PA)**		**Pelvis (AP)**		**Lumbar spine (PA)**	
	Number of rooms	**DAP_{75}**	**Number of rooms**	**DAP_{75}**	**Number of rooms**	**DAP_{75}**
All detectors	1537	21.2	1315	440	859	310
Analogic film	123	24.0	109	505	74	330
Phosphor plate	757	22.8	766	460	482	327
Flat panel	657	16.4	440	358	303	261

Table 3: Summary of Volume Computed Tomography Dose Index ($CTDI_{vol}$) data analyses, for each CT examination type and adult patients in 2015.

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

Examination type	N 2015	Average weight (kg)	$CTDI_{vol}$ (mGy) [1]			75th/25th
			Current DRL	75th	50th	
Brain	369	-	65	46.3	40.5	1.26
Chest	329	72.3	15	9.2	7.6	1.58
CAP	177	71.1	20	11.3	10.0	1.38
AP	304	72.2	17	12.8	11.2	1.42
Lumbar spine	289	72.9	45	29.7	25.1	1.41

[1] Values refer to measurements in the standard CT dosimetry phantom, 16cm diameter for head and 32cm for trunk.

Table 4: Summary of Dose Length Product (DLP) data analyses, for each CT examination type and adult patients in 2015.

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

Examination type	N 2015	Average weight (kg)	DLP (mGy.cm) [1]			75th/25th
			Current DRL	75th	50th	
Brain	371	-	1050	834	745	1.27
Chest	335	72.2	475	344	285	1.48
CAP	180	70.9	1000	771	680	1.32
AP	308	72.0	800	641	541	1.36
Lumbar spine	295	73.0	700	762	661	1.38

[1] Values refer to measurements in the standard CT dosimetry phantom, 16cm diameter for head and 32cm for trunk.

Table 5: Recommended list of radiographic examinations and related Dose area product (DAP) values per view, updated for 75th percentiles and proposed for 50th percentiles.

Examination type	Current DRL ($cGy.cm^2$)	Proposed DAP ($cGy.cm^2$)	
		75^{th} (DRL)	50^{th}
Chest (PA)	25	20	15
Chest (LAT)	100	60	45
Abdomen	700	400	300
Pelvis (AP)	700	450	350
Hip (AP or LAT)	300	150	110
Cervical spine (AP or LAT)	75	40	30
Thoracic spine (AP)	175	120	90
Thoracic spine (LAT)	275	150	100
Lumbar spine (AP)	450	300	220
Lumbar spine (LAT)	800	450	300
Dental panoramic	20	15	10

Table 6: Recommended list of CT examinations and related $CTDI_{vol}$ and DLP values per sequence, updated for 75th percentiles and proposed for 50th percentiles.

Examination type	$CTDI_{vol}$ (mGy) [1]			DLP (mGy.cm) [1]		
	Current DRL	Proposed		Current DRL	Proposed	
		75th (DRL)	50th		75th (DRL)	50th
Brain	65	46	40	1050	850	750
Chest	15	10	8	475	350	300
Chest-abdomen-pelvis (CAP)	20	12	10	1000	800	700
Abdomen-pelvis (AP)	17	13	11	800	650	550
Lumbar spine	45	30	25	700	770	670
Chest-abdomen	-	12	10	-	600	-
Heart – prospective ECG	-	26	12	-	370	-
Heart – retrospective ECG	-	44	20	-	870	-
Sinus (no contrast)	-	14	-	-	250	-

Table 7: Comparison of radiography DRL updating proposals in France and DRL/75th percentiles from other countries.

Examination type	DAP (cGy.cm^2)				
	Switzerland (2011)	**UK (2012)**	**Germany (2016)**	**Belgium (2016)**	**France (2017)**
Chest (PA)	15	10	15	30	20
Chest (LAT)	60	-	40	-	60
Abdomen	-	250	230	275	400
Pelvis (AP)	250	220	250	350	450
Hip (AP or LAT)	-	-	110	-	150
Cervical spine (AP or LAT)	-	15	-	-	40
Thoracic spine (AP)	-	100	110	-	120
Thoracic spine (LAT)	-	150	140	-	150
Lumbar spine (AP)	235	150	200	-	300
Lumbar spine (LAT)	415	250	350	-	450
Dental panoramic	-	9.3	-	-	15

Table 8: Comparison of CT DRL updating proposals in France and DRL/75th percentiles from other countries.

Examination type	Switzerland[1] (2010)		Australia[1] (2011)		UK[1] (2014)		Greece[1] (2015)		Japan[1] (2015)		Germany[1] (2016)		
	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	C
Brain	65	1000	60	1000	60	970	67	1055	85	1350	60	850	
Chest	15	450	15	450	12	610	14	480	15	550	10	350	
Chest, abdomen and pelvis (CAP)	15	1000	30	1200	13	1000	17	1020	18	1300	13	1000	
Abdomen and pelvis (AP)	15	650	15	700	15	745	16	760	20	1000	15	700	
Lumbar spine	30	850	40	900	-	-	35	725	-	-	25	-	
Sinus	25	350	-	-	-	-	52	605	-	-	8	200	

[1] refer to measurements in the standard CT dosimetry phantom, 16cm diameter for head and 32cm for trunk.

[2] refer to median water-equivalent diameter: 15cm for head, 31cm for chest, AP and CAP.