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CT Working Group

On the use of Diagnostic Reference Levels in CT

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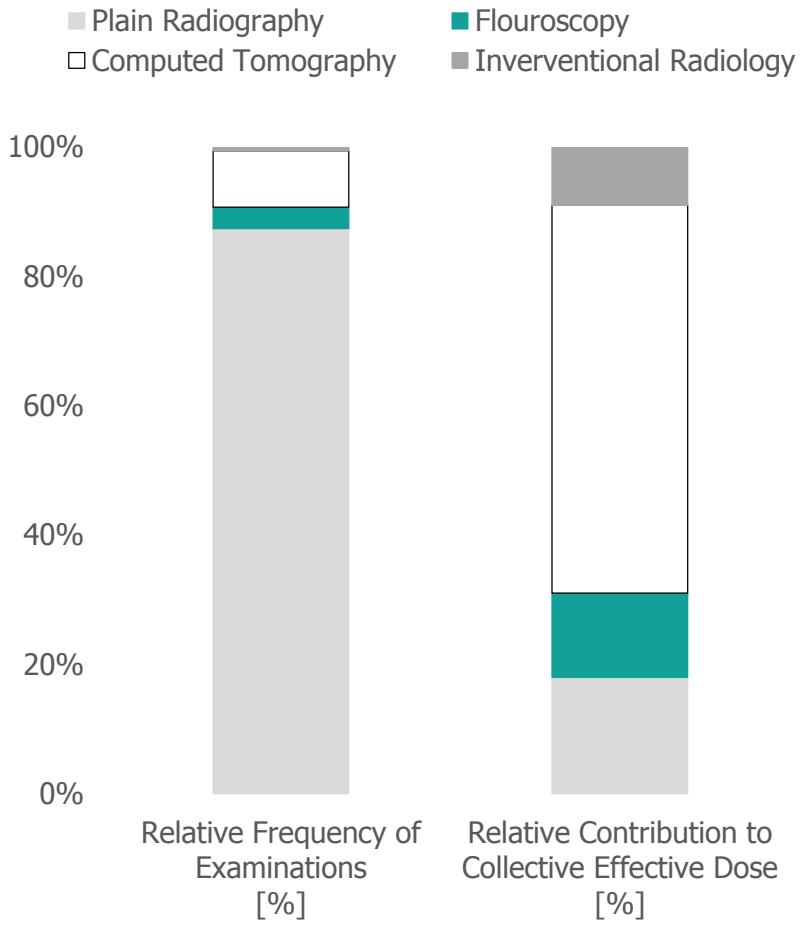
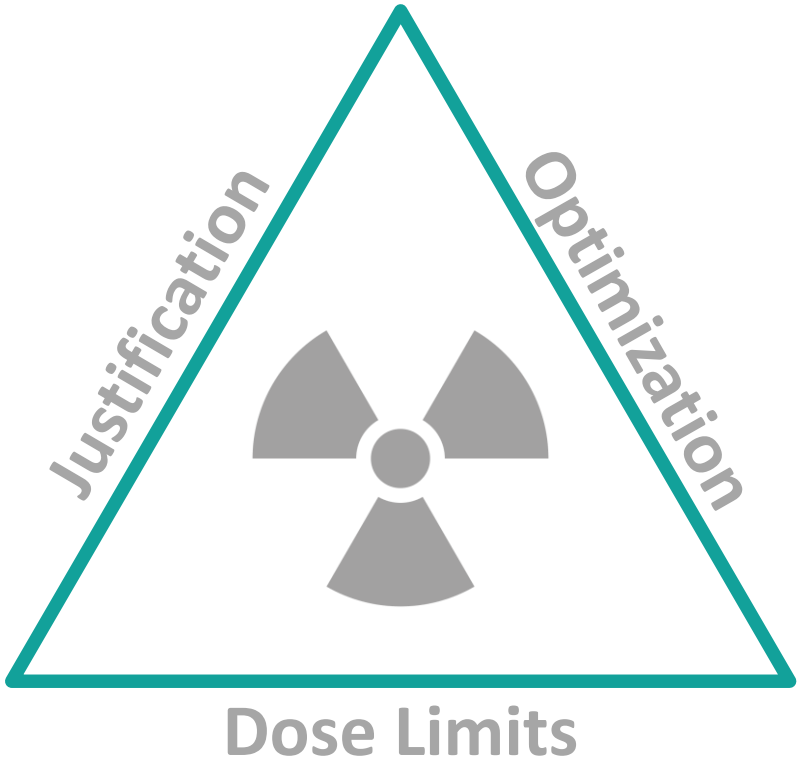
Background

- Computed Tomography (CT) is associated with relatively high radiation doses [1].
- The number and variety of CT examinations has increased steadily over the years and is expected to increase in the future [2].
- CT accounts for the largest contribution of any X-ray imaging modality to the collective effective dose in Europe (see figure) [3].
- Radiation protection in CT is therefore important.



Fundamental principles of radiological protection



The ICRP has 3 fundamental principles of radiological protection [4]:

- **Justification**: Any exposure to radiation should do more good than harm.
- **Optimization**: Exposure to radiation should be kept as low as reasonably achievable (ALARA).
- **Dose Limits**: The total dose to any individual from planned exposures (except for medical reasons) should not exceed appropriate dose limits.

Radiological protection in medicine

- Dose limits are not recommended by the ICRP for individual patients as this may jeopardize the effectiveness of a patient's diagnosis or treatment [4]. The emphasis of radiation protection in medicine is on justification and the optimization of radiation protection [5].

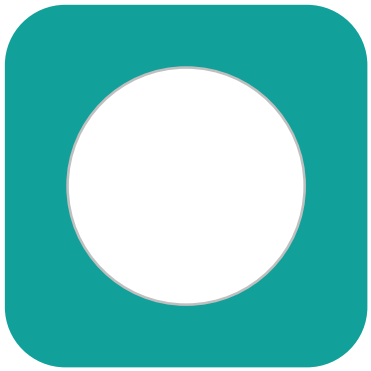
- X-ray imaging exams that are considered to be optimized use a level of radiation dose that is commensurate with the diagnostic task, i.e, radiation doses are not in excess of what is needed for diagnostic confidence [6].

- The Diagnostic Reference Level (DRL) is a tool to "trigger" an investigation and appropriate action if the locally administered radiation dose, for a specific type of exam, deviates from what is considered by an authority or professional organization to be achievable [5].

Basic concept of the DRL [5]

- DRL's are issued for standard and frequent types of examinations (e.g., Routine CT Head or Routine CT Chest) by authorities and/or professional organizations and can be specific to a country, region or locality.
- A DRL is a dosimetric quantity that is practical to measure and reproducible. When DRL's are chosen, the distribution of a wide sample of observed levels of radiation dose (surveys), for a specific type of examination, is taken into consideration (e.g., the 75th percentile).
- A DRL represents a level of radiation dose for a reference group of patients (e.g. within a weight range or age for pediatrics).
- For a specific type of examination, the local radiation dose level under routine conditions is calculated for a reference group of patients and compared to the DRL. Appropriate review and action should be taken if the local radiation dose exceeds the DRL.

DRL's in Practice (1)



A CT scanner is used for a specific imaging task and reports the $CTDI_{vol}$ and DLP.

The distribution of the reported $CTDI_{vol}$ and DLP for a sample of, e.g. 20, standard-sized patients is analyzed for that type of examination and CT scanner.

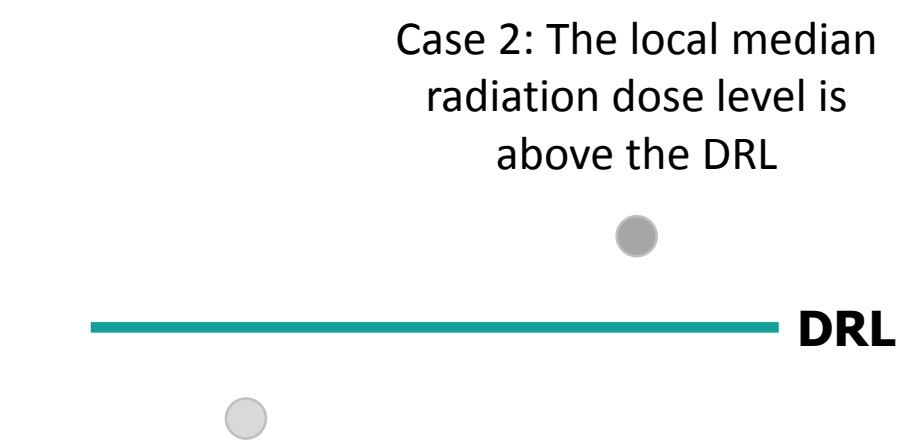
European, National, Regional or Local DRL

The median value of the $CTDI_{vol}$ and DLP are compared with the relevant DRL for that specific imaging task.

Take note, this is an example of using DRL's in practice, consult your local regulations on the application of DRL's in your country or region.

DRL's in Practice (2)

- In the event that the local radiation dose level for a specific imaging task exceeds the DRL, this should trigger an investigation as to the reason why the DRL has been exceeded.
- The issuer of the DRL should provide guidance on what actions to take if the DRL has been exceeded.
- Factors such as image quality (diagnostic confidence) and justification are important to consider in the investigation.



Working with DRL's in CT

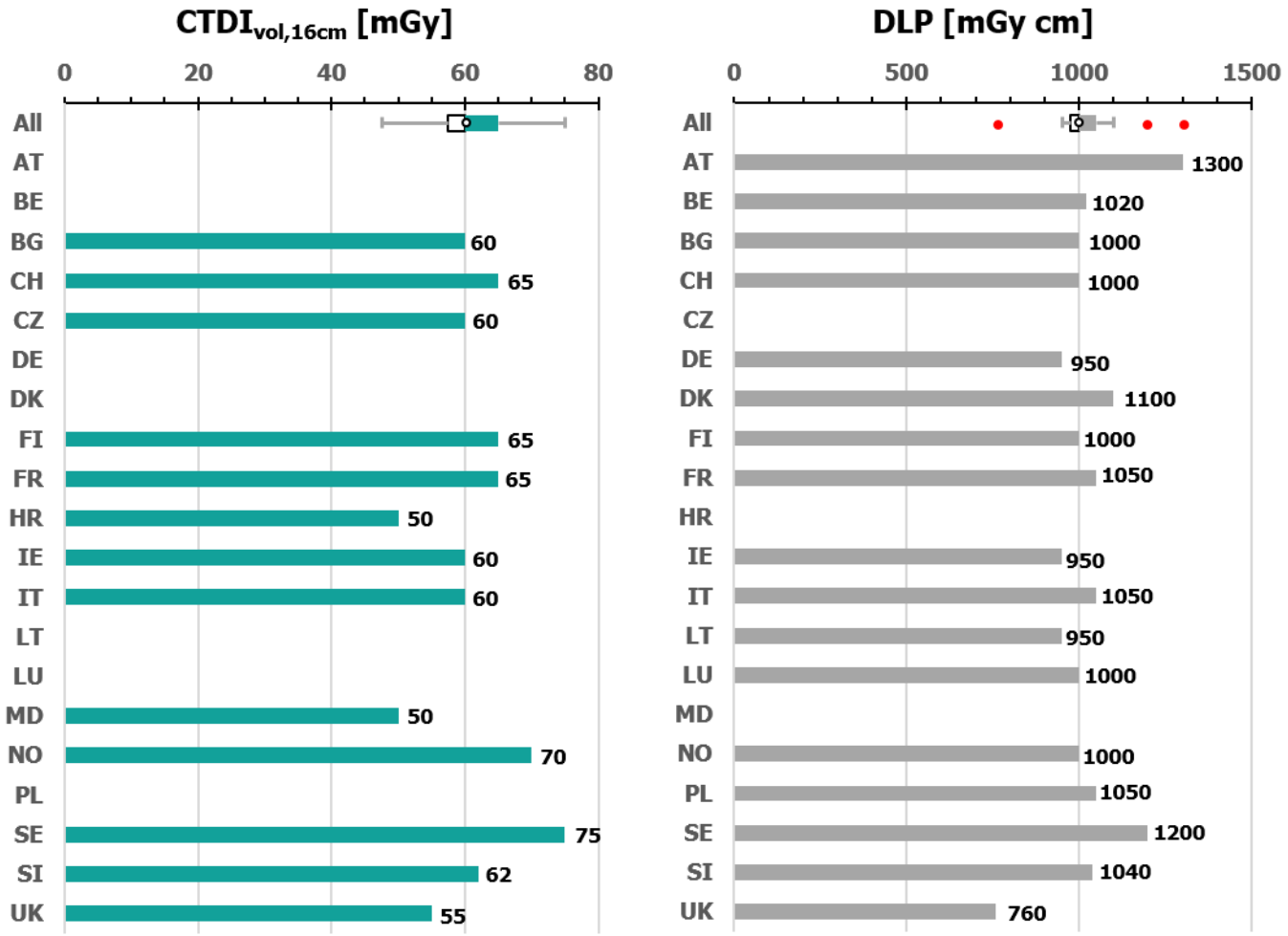
- Comparison of the local radiation dose levels with appropriate DRL's is considered to be an integral part of a quality assurance program. Further, DRL comparisons should be made on a periodic basis and after major changes on a CT scanner [7].
- The European Guidelines on DRLs for Paediatric Imaging will soon be published by the European Commission. In this report, additional guidance on the use of DRLs with specific regard to pediatric imaging can be found.
- The ICRP is working on a report dedicated to diagnostic reference levels in medical imaging to provide additional guidance on its usage.

2014 Survey on National DRL's in Europe

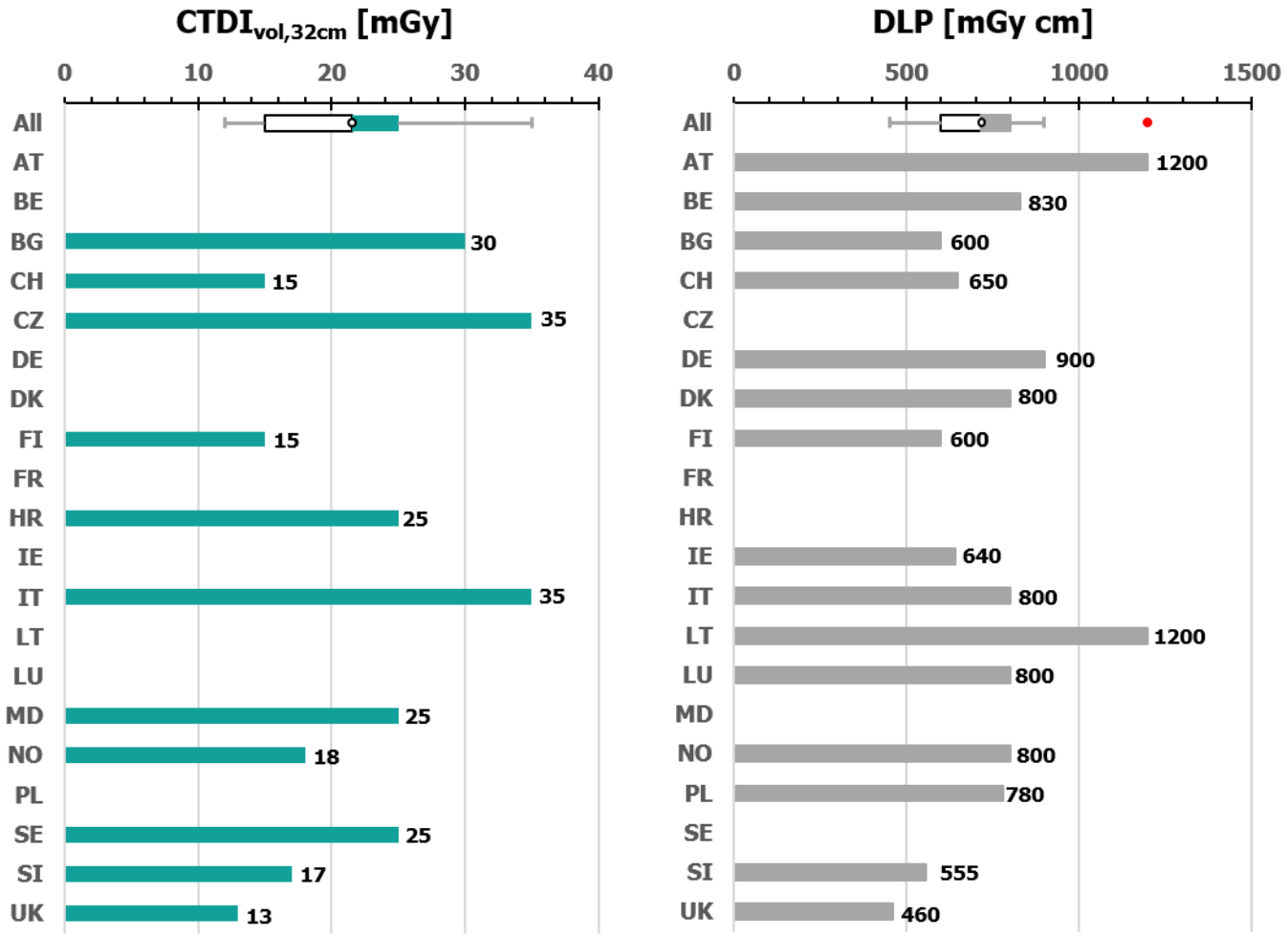
- This table shows the prevalence of NDRL's in Europe [8].
- **1** and **2** represent an NDRL issued as DLP [mGy cm] or $CTDI_{vol}$ [mGy], respectively.
- The remainder of European countries either do not have NDRL's or were not included in the survey (ref. [8]).
- Take note, NDRL's may have been updated since 2014.
- The following slides present NDRL values for CT Head and CT Abdomen.

Country Code	Head	C-Spine	Neck	Routine Chest	HRCT Chest	Upper Abdomen	Abdomen	Pelvis	Lumbar Spine
AT	1			1		1	1	1	
BE	1			1			1		1
BG	1, 2			1, 2			1, 2	1	
CH	1, 2	1	1	1, 2		1	1, 2	1	1, 2
CZ	2						2		2
DE	1			1		1	1	1	1
DK	1		1	1	1		1	1	
FI	1, 2			1, 2			1, 2		1, 2
FR	1, 2			1, 2					1, 2
HR	2						2		2
IE	1	1		1	1		1		
IT	1, 2			1, 2			1, 2	1	
LT	1			1			1	1	1
LU	1	1	1	1			1		1
MD	2						2		2
NO	1, 2	1		1, 2			1, 2		1, 2
PL	1			1	1		1	1	
SE	1, 2			1, 2			2		1, 2
SI	1, 2			2			1, 2		
UK	1, 2			2	1		1, 2		

NDRL's for CT Head in Europe [8]



NDRL's for CT Head in Europe [8]



Caveats with DRL's in CT

- The European Union has promoted the use of DRL's through COUNCIL DIRECTIVE 2013/59/EURATOM (and previous directives thereof). However, the application of DRL's through national authorities in Europe can differ greatly (DRL values, methods of calculation, imaging tasks covered etc) [8]. It is therefore important to consult with national or regional regulations when applying DRL's in local practice.

- A DRL represents achievable practice at a given point in time. Depending on when a DRL was issued, it might not be appropriate for your local practice considering the recent technological advances that can reduce the level of radiation dose in CT [9].

- Compliance with DRL's does not in and of itself guarantee that your local practice is optimized. Other factors such as justification, clinical task and image quality must be taken into consideration [5].

Clinical DRL's [10]

- Current DRLs are generally issued for a specific anatomical location, e.g., CT Head or CT Abdomen.
- Anatomical DRLs do not reflect clinical tasks that require different levels of exposure.
- Anatomical DRLs are therefore not appropriate across all indications (e.g., CT Sinuses requires appreciably less dose than a CT Brain).
- The ESR, through EuroSafe Imaging, has recently established a workgroup with the charge to develop a set of clinical DRLs that will be based on indication rather than anatomical location.
- Clinical DRLs through the ESR are intended to be used as a compliment to other existing (e.g. National) DRLS.

Additional Aspects

- Radiation Dose Structured Reporting (RDSR) has become a standard feature on modern CT scanners. The widespread collection and analysis of the dose metrics $CTDI_{vol}$ and DLP from patient examinations (through e.g., dose monitoring software) is now possible. With adequate data, local DRL's can be implemented in addition to evaluating compliance with other DRL's.

- The dose metric Size-Specific Dose Estimate (SSDE) [11] corrects the $CTDI_{vol}$ to account for the actual patient size. DRLs based on the SSDE have been reported for a number of examinations, however, they are not readily implemented as CT scanners currently do not report the SSDE [12].

Conclusions

- Diagnostic Reference Levels (DRL) in CT are currently based on the $CTDI_{vol}$ and DLP.
- The DRL is applicable to a representative group of patients and should not be used on an individual basis nor as a dose limit.
- DRLs can be issued on a national or regional level and are associated with specific types of exams.
- A DRL is an advisory radiation protection tool that is used by medical professionals to "trigger" reviews and actions when the local radiation dose is considered unnecessarily high.
- DRLs differ throughout Europe, when applying DRLs in local practice, national, regional or local regulations need to be consulted.
- There is a drive towards indication-based DRLs to take the clinical task into account.

References

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[7] European Commission. "Radiation Protection No 109: Guidance on diagnostic reference levels (DRLs) for medical exposures". European Union, 1999.

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[11] American Association of Physicists in Medicine (AAPM). "AAPM Report No. 204: Size-Specific Dose Estimates (SSDE) in Pediatric and Adult Body Examinations", AAPM, 2011.

[12] Kanal KM, Butler PF, Sengupta D, Bhargavan-Chatfield M, Coombs LP, Morin RL. US diagnostic reference levels and achievable doses for 10 adult CT examinations. Radiology. 2017 Feb 21:161911.