Establishment and utilization of diagnostic reference levels in medical imaging: Results from a survey and consultation under the IAEA technical cooperation programme in Europe and Central Asia

Dario Faj\textsuperscript{a,b}, Sue Edyvean\textsuperscript{c}, Atte Lajunen\textsuperscript{d}, Alexey Katukhov\textsuperscript{e}, Jenia Vassileva\textsuperscript{f,∗}

\begin{itemize}
\item \textsuperscript{a} Medical Faculty, University Josip Juraj Strossmayer, Osijek, Croatia
\item \textsuperscript{b} Faculty of Dental Medicine and Health, University Josip Juraj Strossmayer, Osijek, Croatia
\item \textsuperscript{c} UK Health Security Agency, Radiation, Chemical and Environment, Chilton, UK
\item \textsuperscript{d} Radiation and Nuclear Safety Authority STUK, Helsinki, Finland
\item \textsuperscript{e} Department of Technical Cooperation, International Atomic Energy Agency, Vienna, Austria
\item \textsuperscript{f} Radiation Protection of Patients Unit, International Atomic Energy Agency, Vienna, Austria
\end{itemize}

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\paragraph*{ABSTRACT}

The paper presents the results of the activities under the IAEA Technical Cooperation programme in Europe and Central Asia, aiming to improve utilization of diagnostic reference levels (DRLs) in the region through identifying status, problems, and gaps in establishing and utilization of the DRLs, and suggesting potential solutions. Status was identified through a survey with two electronic questionnaires answered by the regulatory bodies for radiation protection of 26 IAEA Member States and 34 representatives of relevant professional bodies of medical physics, radiology, nuclear medicine or radiographers. Problems, good practices and potential solutions were identified as a result of the discussion during a regional workshop with 50 nominated representatives of 21 countries. Results were disseminated through open webinars. Existing gaps are related to the lack of adequate regulations in some countries, inadequate awareness of radiological professionals of DRLs as a tool for optimization, insufficient cooperation among relevant stakeholders, education, and staffing. Strengthening of the cooperation between regulatory and professional bodies could benefit the awareness and consequently the utilization of DRLs in clinical practice. The need of improved education and training of the DRL process was highlighted. Improved inspection procedures and education of inspectors would also support the process. Access to clinically qualified medical physicists was found to be critical for the DRL utilization. Suggestions were placed for continuous IAEA assistance through training, guidance and expert support.

\section{1. Introduction}

Medical exposure is by far the largest source of exposure to the human population from all man-made radiation sources [1]. In order not to limit the benefit for patients, no dose limits apply to medical exposure, and the efforts are towards improved implementation of principles of justification and optimization [2,3]. The Diagnostic Reference Level (DRL) is defined as “a level used in medical imaging to indicate whether, in routine conditions, the dose to the patient or the amount of radio-pharmaceuticals administered in a specified radiological procedure for medical imaging is unusually high or unusually low for that procedure” [3]. Requirements for DRL establishment and utilization are included in the International Basic Safety Standards (BSS), GSR Part 3 [3] and the EU BSS Directive [4], which are expected to be transposed into the respective national legislations. Additional guidance for the implementation of DRLs in practice was published by the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) [5,6]. A previous IAEA consultancy found that some countries still lack the legislative basis and appropriate infrastructure for effective patient dose management [7]. Even when DRLs are included in the regulatory requirements, they have not been implemented in many countries for various reasons, such as lack of resources, in particular clinically qualified medical physicists (CQMP), insufficient awareness on the importance of optimization, bureaucratic...
top-down approach practiced by some regulatory bodies, and insufficient cooperation among key stakeholders [7–9].

The IAEA provides technical cooperation (TC) support to 33 countries in the Europe and Central Asia region. Within the IAEA TC programme, the regional project RER9/147 was designed for Member States (MSs) in the TC Europe region to improve the implementation of the framework of radiation protection in medical uses of ionizing radiation, and to enhance the national capabilities for medical exposure control in compliance with requirements of the GSR Part 3 [3]. The main goals of the project were to strengthen the cooperation of regulatory bodies, health authorities and relevant professional bodies, and to enhance their capacity in ensuring the implementation of the basic requirements for radiation protection and safety related to medical exposure. Analyses of the national legislation of the participating MSs made under the project showed large variations in the status of implementation of the requirements of the International BSS for using DRLs as a tool for optimization of radiation protection of patients. These findings have initiated activities under the project aiming to improve utilization of DRLs in the region through identifying status, problems, and gaps in establishing and utilization of the DRLs, and suggesting potential solutions. This paper presents the results of these efforts, including a survey and workshop aimed to identify gaps, solutions and potential actions in order to improve national regulatory framework and implementation of the DRL process in the region.

2. Methods and materials

The data relating to establishing and utilization of DRL in medical imaging were gathered using two electronic questionnaires in Google Forms, with multiple-choice questions addressing two main target groups – regulatory bodies for radiation protection (related to medical exposure) and professional bodies.

The questionnaire for the national radiation protection regulatory body consisted of the following sections: information about country and institution, and seven sections with identical questions to find out if and how the DRLs are established for different modalities. General radiography, mammography, computed tomography (CT), general fluoroscopic examinations, fluoroscopy guided interventional (FGI) procedures, dental radiography and diagnostic nuclear medicine (NM) procedures were included. If DRLs were established, then the process of the DRL establishment was questioned: who is involved, how often the DRLs are updated and for when next update is planned, is the DRL adopted from another source or established based on a patient dose survey, how data are collected, what percentage of the equipment is included, how the procedures were chosen, what was the number and which patients were included, etc. The last section included questions of the DRL utilization in hospitals and inspection of this process. The number of questions to be answered varied depending on the answer to the primary questions, but for countries with DRLs available for all modalities, there was a total of 53 questions.

The questionnaire for relevant professional bodies consisted of 14 questions. It investigated awareness of the DRL framework existence among relevant professionals as well as their involvement in the DRL establishment and their cooperation with the regulatory body. Further questions were designed to investigate the opinion of the relevant professionals on the extent of DRL utilization in clinical practice, and if it is checked during the inspection process.

The electronic questionnaire was distributed to the formally nominated national counterparts requesting them to forward it to the relevant national contacts in the regulatory body and all relevant professional bodies. One answer was expected from each national regulatory body, as well as from each relevant professional body.

The survey was opened for five weeks, during which reminders were sent by the IAEA coordinator.

Results were thematically analysed by the IAEA experts who developed the surveys. The responses from different bodies in the same country were compared to acquire a better insight into the DRL utilization and involvement of different stakeholders. Survey results were analysed and presented using descriptive statistics.

Member States participating in the regional project were invited to nominate their representatives for a three-day virtual workshop on implementation of DRLs in TC Europe MSs organized by the IAEA. The objective of the workshop was to review the status of implementation of the requirements of the International BSS for using DRLs as a tool for optimization of radiation protection of patients, identify gaps and share good practices. The analysis of the survey results was used as the basis for the workshop. During the event, results of the surveys were presented, and discussion of the participants was organized and moderated by the experts, initially in smaller groups, followed by a whole group discussion. Dissemination of the results was organized through two webinars with free registration for all interested parties.

3. Results

3.1. Questionnaire for the national regulatory bodies

Responses to the corresponding survey questionnaire were received from the national regulatory bodies of 26 IAEA MSs (79 % response rate), 14 (54 %) of which were also MSs of the European Union (EU) (Table 1).

Analysis revealed that 16 out of 26 countries (62 %) have national DRLs established for mammography, 15 (58 %) for radiography, 13 (50 %) for CT procedures, 12 (46 %) for diagnostic NM procedures, 9 (38 %) for fluoroscopy, 9 (35%) for FGI procedures, and 8 (31 %) for dental radiology procedures. The separate analysis for EU and non-EU MSs showed that DRLs are more often established in the EU MSs (Fig. 1).

Analyses showed that if DRLs are established, they are older than 5 years in more than 30 % of cases. The DRL values are most often established based on wide scale national studies, but sometimes they are adopted from other country, or published values (Fig. 2). When the DRLs are adopted, the resources referred in the questionnaire are DRLs from other countries [10], but also some obsolete documents of the IAEA and EC.

Responses of regulatory bodies revealed that very few other institutions or societies are involved in establishment of national DRLs. In the cases where institutions other than the regulatory body are involved, these are medical physics societies or research institutes with medical physicists available.

Submission of electronic forms via e-mail is the most common method for the DRL data collection, but paper forms via post or email, or submission through dedicated online platform are also used. Usually more than 30 % of all X-ray equipment in the country is involved in the DRL surveys, except in dental radiology where this percentage is lower. In over 80 % of the countries with established DRLs, patient weight for data collection is restricted to that of a ‘standard patient’ as recommended by ICRP [5]. The number of patients in samples requested per institution/ procedure was between 10 and 50, varying from 10 to 20 patients for radiography and dental radiology, and from 10 to 50 patients in mammography, fluoroscopy, FGI, CT and NM procedures.

DRLs for SPECT or PET procedures exist in 12 countries, however, a CT component of hybrid imaging is included in only four of them.

When the implementation of the DRLs in clinical practice is considered, the main question addressed to the regulatory body was whether there is a regulatory requirement to ensure that local assessments of typical dose values for most common radiological and NM procedures are made by the clinical staff in medical facilities. The answer was positive for all EU MSs, and for 67 % of other countries in the TC Europe region. An interesting observation was that such a requirement exists in some countries even if the DRLs are not established. Similarly, requirements for corrective actions if typical doses exceed the relevant DRLs sometimes exist even DRLs are not established for a given radiological procedure. Such requirement exists in all EU MSs and 50 % of
other countries participating in this project. However, requirement for corrective actions if typical doses fall substantially below the relevant DRLs for a given radiological procedure exists in only 5 out of 14 (36%) EU MSs and 5 out of 12 (42%) non-EU MSs.

Another surveyed aspect of DRL utilization was the inspection of DRL utilization in hospitals. Fig. 3 shows answers of the regulatory bodies as to how often inspection includes DRL utilization by checking the documented existence of local typical doses and their comparison to the DRLs.

According to the answers from the national regulatory bodies, guidelines for using national DRL exist in 8 out of 26 countries and they are usually given on the webpage of the regulatory body. The last question in this questionnaire was whether dose monitoring systems (DMSs) exist in the hospitals. The answers indicated that DMSs do not exist in small hospitals and are very rare in medium and large hospitals.

### 3.2. Questionnaire for the professional bodies

The survey for professional bodies was meant to be answered by the medical physics, radiology, NM, radiographers and other relevant societies, and when such did not exist or did not respond to the invitation, answers were provided by individual members of societies. 34 answers were received to this questionnaire, about half of them were provided by a nominated representative of the society, and the rest by individual members. Most of the answers (9) were from medical physics societies or from individual medical physicists (11). Fewer answers (5) came from radiology societies, individual radiologists (4), nuclear medicine society (2) or radiation technologists / radiographers societies (3). No answer was received from societies of healthcare professionals performing interventional procedure, except two answers by individual members (interventional radiologist and interventional cardiologist). Only 4 countries provided answers from more than one relevant professional societies. Details are shown in Table 1.

Only six respondents claimed that the professional bodies were officially called and represented in the establishment of DRLs. In other cases, individual professionals were involved if any.

The answers to the question to estimate how many (in terms of four percentage ranges) of the organisation members are aware of the existence of national DRLs are presented on Fig. 4. The figure also shows same estimations provided by the representatives of those six organizations that were officially invited to take a part in the DRL establishment. Five of these six respondents (83%) claimed that over 50% of their members are aware of the existence of national DRLs, while this percentage is lower when considering all answers (14 out of 34 respondents, or 41%).

Fig. 5 shows answers to the question “In your opinion, is the understanding of the application of DRLs sufficiently included in the education and training of professionals from your organization?” Answers of the representatives of the professional bodies of radiological medical practitioners (radiologists or NM physicians) are shown separately from those of all others, including medical physicists and radiographers.

According to the answers of 22 out of 34 (64.7%) responding professional bodies, the utilization of DRLs in clinical practice is at least partially inspected by their national regulators. This result is similar to the answers obtained from the regulatory bodies, where 16 respondents (61.5%) claimed that the utilization of DRLs is included in inspection, as presented in Fig. 3.

Estimations of utilization of the DRLs in radiography, mammography and CT according to the size of the hospitals are presented in the Fig. 6.

Similar answers were given for fluoroscopy, FGI and NM procedures, but these answers should be taken with caution since these procedures are rarely performed in small hospitals.

The last question in this questionnaire was whether dose monitoring systems (DMSs) exist in the hospitals. The answers indicated that large hospitals use DMSs more often, but DMSs are sometimes used also in smaller institutions (Fig. 7).

### 3.3. Online workshop

The online regional workshop with 50 nominated representatives of 21 MSs participating in the TC project RER9/147 took place in
September 2021. After setting the scene with lectures of DRLs and patient dose audits in the international standards and guidelines, the status of implementation of DRLs in the national legislation, results of the survey for the regulatory bodies and results of the survey for the professional bodies were presented.

The meeting continued in three break-out groups with tasks to identify problems, share good practices and propose potential solutions. The discussions identified that some of the countries do not have legislation complying with GSR Part 3, some of the countries have no or very few CQMP available in hospitals, with no DRL utilization in clinical practice (or only in large hospitals). On the other hand, there are countries with established DRL values and utilization of DRLs in clinical practice as an optimization tool. Different priorities were identified for these countries for strengthening establishing and utilization of DRLs at national level. Problems were prioritized from higher to lower importance having in mind that some countries had successfully dealt with some of the problems. It was concluded that all problems are of relevance to all countries but with different importance and priority order. During the workshop, a number of potential solutions were proposed, some of them general and applicable to all countries, while some are country specific. The identified issues and the proposed solutions are summarised in Table 2.

Fig. 1. Availability of national DRLs by imaging modality, given in percentages of all Member States. For each modality, blue bars show the absolute number of countries in the group of EU Member States, and the red bars – the others non-EU Member States from the IAEA TC Europe region.

Fig. 2. Answers to the questions “What method was used to define latest/ current national DRLs?”. The answers for different imaging modalities are shown in absolute numbers of responses.
4. Discussion

The IAEA coordinated survey on establishment and utilization of DRL in the TC Europe and Central Asia region showed a number of gaps, such as lack of adequate regulations in some countries, inadequate awareness of radiological professionals of DRLs as a tool for optimization, insufficient cooperation among relevant stakeholders, education, and staffing. The survey showed that DRLs are established more frequently in the EU MSs and less frequently in other countries participating in the IAEA TC programme in Europe and Central Asia (Fig. 1). Further investigation showed that the situation is similar with the existence of requirements to ensure local assessment of typical doses in clinical practice, and for corrective actions if typical doses exceed relevant DRL. The requirement for corrective actions if typical doses fall substantially below the relevant DRL is missing also in most EU MSs, that can be explained by the fact that this specific requirement of the International BSS is not included in the European Directive, while most of other requirements related to DRLs and patient dosimetry are similar in both the International and European BSS [3,4]. The better harmonisation of the national regulation with the International BSS requirements in the EU MSs compared to others can be explained with the binding EU directive that had to be transposed into the national legislation in 2018 year [4].

In countries with established DRLs, data are collected preferably using electronic forms. The guidelines given in relevant documents [5,6] on how to select the procedures, equipment and patients, are usually followed. However, if the DRLs are established, they are older than 5 years in more than 30 % of cases and sometimes adopted from other, even obsolete, sources (Fig. 2). It means that DRL values often do not reflect the practice in the country or do not follow the technological advances in medical imaging, making utilizing the DRLs in the optimization process not as useful as intended.

The survey revealed insufficient cooperation among relevant stakeholders. Answers to both questionnaires showed that usually some professionals are invited to help with the DRL surveys, and very rarely the professional bodies are officially invited. Furthermore, analyses of the responses from the professional bodies showed that in only four countries more than one relevant professional society responded and, in other countries, responses were mostly given by regulatory body and one individual belonging to the relevant professional body, but not
representing the organization (Table 1). More than half of the answers on the second questionnaire were given by medical physicists, though establishing DRLs are likely to involve many parties [6]. All of these implies inadequate cooperation of regulatory body with all relevant professional bodies, despite the existing requirement in the International BSS that “the government shall ensure, …, that as a result of consultation between the health authority, relevant professional bodies and the regulatory body, a set of diagnostic reference levels is established for medical exposures incurred in medical imaging, including image guided interventional procedures” [3]. Furthermore, the DRL concept can serve its intended role as an optimization tool only if implemented into the clinical practice and appreciated by the clinical staff [8]. This requires closer collaboration between regulatory bodies and professional societies on all phases of the DRL cycle [7,8]. Surprisingly, very few respondents claimed that their professional body were involved in the DRL establishment (Fig. 4). The percentage of respondents who claimed that over 50% of their members are aware of the existence of national DRLs was twice higher for the professional bodies that were involved in the establishment of DRLs, compared to the total number of respondents. This is a positive trend, although the low number (6 out of 34) of professional bodies involved in the establishment of DRLs does not allow for making a statistically significant conclusion about its correlation with the increasing awareness on the DRL. Another published study showed that 79.9% of members of the Japanese Society of Radiological Technology knew that DRLs were released in Japan [11].

One of the most important factors in the utilizing the DRLs in the clinical practice is the education of all involved professionals [5–8]. The results of the survey showed that most of the participants expect DRLs to be better included in the education and training of professionals involved. This is in line with previously published IAEA coordinated studies [12,13]. Moreover, Fig. 5 shows that this is especially true for the radiological medical practitioners (radiologists and NM physicians).

The survey also confirmed that DRLs are utilized in the optimization process more often in large hospitals than in small hospitals (Fig. 6). This can be partly explained with the better access to medical physicists in the large hospitals due to existence of large radiology and NM departments. Also, large hospitals use DMSs more often (Fig. 7) what helps in DRL utilization.

Professional bodies estimations of DMS existence in hospitals
differed significantly from the answers of the regulatory bodies. Though regulatory bodies claim that there are very few DMSs in large hospitals and practically none in smaller institutions, professional bodies in some countries answered that approximately 50% of large hospitals use DMSs but they are also available in smaller institutions. It can imply that regulatory bodies are not always aware of state of radiation protection of patients in hospitals.

Several gaps were identified, and potential solutions were proposed (Table 2). Some of these solutions have been confirmed in the examples of good practices in establishment and utilization of DRLs presented during the workshop by some of the MSs. From these good practice examples, participants recognized approaches that could facilitate establishment and utilization DRLs in clinical practice:

- The common factor of all successful national surveys for the establishment of DRLs was the existence of teamwork and cooperation between the health authority, regulatory body and professional societies; achievable even if legal framework is missing or inadequate, such as in the one of the presented examples.
- All countries with successful DRL projects presented a number of small-scale surveys performed before the national surveys, through which capacity for larger data collection and analyses at national level was built. This approach is recommended for countries that are still to start the process.
- The utilization of DRLs as an optimization tool in hospitals exists mostly in large hospitals with CQMPs employed, that are transferring knowledge to others. This emphasizes the importance of involvement of CQMPs in diagnostic imaging departments.
- Examples were shown of using automatic dose data monitoring software to facilitate data collection and analyses. The experience of one country with installing such a system at national level, revealed challenges that need to be considered when planning such a nationwide project.
- In one country, DRL utilization is assessed during the licensing process, when the facilities are obliged to submit their typical doses, as well as during the regular inspections. The topic is included in the training of regulators/inspectors, majority having medical physics background.
- In another country, in addition to the paper and electronic data collection forms, an online dose data submission platform was created, and a national database from all dose surveys was maintained by a national governmental institution.
- Some countries used IAEA TC projects (regional or national) to establish their first national DRLs and to raise knowledge and awareness, and in others such national TC projects are planned with involvement of all relevant stakeholders.

Suggestions were placed for continuous IAEA assistance through training, guidance, and expert support. The new IAEA eLearning on DRLs, available in English and Spanish, and under translation in Russian language, was seen as a useful tool for training on the topic [14]. The results of the survey and the outcomes of the regional workshop were disseminated through two open webinars, one of which with an invited contribution from the EuroSafe Imaging [15].

5. Conclusions

The surveys among regulatory and professional bodies of the MSs participating in the IAEA TC programme in Europe and Central Asia showed insufficient awareness of the DRL concept and existing DRLs among medical imaging professionals. Since the surveys also imply that cooperation of regulatory bodies with relevant professional bodies is sometimes inadequate, the strengthening of the cooperation could benefit the awareness and consequently the utilization of DRLs in clinical practice. The need of improved education and training of the DRL process was highlighted. DRL utilization is not properly integrated into the inspection processes of the regulatory bodies, showing the need of improved inspection procedures and education of inspectors. Access to clinically qualified medical physicists was found to be critical for the DRL utilization. The workshop identified good practices in the region and proposed solutions for improving the establishment and utilization of DRLs as an optimization tool. IAEA information and training resources available through the Radiation Protection of Patients website [16] and the technical assistance through the Technical Cooperation programme [17] were found to be of importance for this process.

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Fig. 7. Participant estimations of percentage of hospitals that utilize DMSs. The answers are presented in terms of absolute numbers of responses according to the hospital size using different colours.
Table 2
Identified issues and solutions proposed by the participants of the regional workshop.

<table>
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<tr>
<th>Issues identified</th>
<th>Proposed solutions</th>
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<tr>
<td>Lack of legislation, supervision, coordination and leadership, human resources at the regulatory body</td>
<td>Align legislation related to DRLs and patient dosimetry with the recent international standards and recommendations, with roles and responsibilities clearly defined and adapted to the local situation. Develop guidance on the implementation of the DRL process in clinical practice, highlighting the importance of the cooperation between the key stakeholders at national level (government, regulatory body, professional societies, hospitals), as well as teams involving medical professionals, radiographers and medical physicists at radiological facilities. Regularly update the legislation, guidelines, plan own surveys to establish/update DRL values, as well as consider adoption of international guidelines (if they have not developed their own yet). In settings where medical physicists are not available in the hospital, the responsibilities for quality control, calibration, dose data collection, corrective actions, etc. might be performed by external medical physics services, with ensuring their adequate competence and clinical experience. Include in the education and training programmes of health professionals sufficient information about the DRL process as a tool for optimization, organize regular activities to build awareness such as presentations at national congresses and meetings. In every radiological facility, organize regular meetings of medical radiological professionals, radiographers and medical physicists to discuss optimization and implementation of DRLs. Establish a Task Group with involvement of professional bodies for the development of a common methodology and harmonized protocols. Facilitate/promote installation in medical facilities of automatic exposure monitoring systems (dose data management software) and ensure that quality control of these systems is performed by or under the supervision of a qualified medical physicist. Ensure that the technical specifications of the newly procured imaging systems include as an integral part dose measuring/indicating equipment or software. Establish a Task Group with involvement of professional bodies for the development of a common methodology and harmonized protocols. Join efforts of countries at regional/sub-regional level, to establish regional DRLs for paediatric examinations. Publish numerical values of DRLs in a document/format that can be easily amended when values are updated, and these numbers do not need to be a part of the legislation.</td>
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<td>Lack of clinically qualified medical physicists in radiology departments.</td>
<td>- Including DRL numerical values as a part of legislation cannot be changed easily.</td>
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<tr>
<td>Lack of staff education and awareness among professionals and regulators, lack of involvement of relevant professional societies.</td>
<td>- Including DRL numerical values as a part of legislation cannot be changed easily.</td>
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<td>Lack of harmonized data collection and reporting methodology, including decision of the data type, equipment and protocol, how to collect data, how to verify/correct data collected with local measurements, how to classify and select procedures (names, clinical indication, etc.)</td>
<td>- Align legislation related to DRLs and patient dosimetry with the recent international standards and recommendations, with roles and responsibilities clearly defined and adapted to the local situation. Develop guidance on the implementation of the DRL process in clinical practice, highlighting the importance of the cooperation between the key stakeholders at national level (government, regulatory body, professional societies, hospitals), as well as teams involving medical professionals, radiographers and medical physicists at radiological facilities. Regularly update the legislation, guidelines, plan own surveys to establish/update DRL values, as well as consider adoption of international guidelines (if they have not developed their own yet). In settings where medical physicists are not available in the hospital, the responsibilities for quality control, calibration, dose data collection, corrective actions, etc. might be performed by external medical physics services, with ensuring their adequate competence and clinical experience. Include in the education and training programmes of health professionals sufficient information about the DRL process as a tool for optimization, organize regular activities to build awareness such as presentations at national congresses and meetings. In every radiological facility, organize regular meetings of medical radiological professionals, radiographers and medical physicists to discuss optimization and implementation of DRLs. Establish a Task Group with involvement of professional bodies for the development of a common methodology and harmonized protocols. Facilitate/promote installation in medical facilities of automatic exposure monitoring systems (dose data management software) and ensure that quality control of these systems is performed by or under the supervision of a qualified medical physicist. Ensure that the technical specifications of the newly procured imaging systems include as an integral part dose measuring/indicating equipment or software. Establish a Task Group with involvement of professional bodies for the development of a common methodology and harmonized protocols. Join efforts of countries at regional/sub-regional level, to establish regional DRLs for paediatric examinations. Publish numerical values of DRLs in a document/format that can be easily amended when values are updated, and these numbers do not need to be a part of the legislation.</td>
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<td>Lack of technical equipment and process. For example, lack of dosimetry equipment and software (exposure monitoring systems), quality control, calibration of x-ray equipment, lack of harmonized quality control and dosimetry protocols and procedures</td>
<td>- Align legislation related to DRLs and patient dosimetry with the recent international standards and recommendations, with roles and responsibilities clearly defined and adapted to the local situation. Develop guidance on the implementation of the DRL process in clinical practice, highlighting the importance of the cooperation between the key stakeholders at national level (government, regulatory body, professional societies, hospitals), as well as teams involving medical professionals, radiographers and medical physicists at radiological facilities. Regularly update the legislation, guidelines, plan own surveys to establish/update DRL values, as well as consider adoption of international guidelines (if they have not developed their own yet). In settings where medical physicists are not available in the hospital, the responsibilities for quality control, calibration, dose data collection, corrective actions, etc. might be performed by external medical physics services, with ensuring their adequate competence and clinical experience. Include in the education and training programmes of health professionals sufficient information about the DRL process as a tool for optimization, organize regular activities to build awareness such as presentations at national congresses and meetings. In every radiological facility, organize regular meetings of medical radiological professionals, radiographers and medical physicists to discuss optimization and implementation of DRLs. Establish a Task Group with involvement of professional bodies for the development of a common methodology and harmonized protocols. Facilitate/promote installation in medical facilities of automatic exposure monitoring systems (dose data management software) and ensure that quality control of these systems is performed by or under the supervision of a qualified medical physicist. Ensure that the technical specifications of the newly procured imaging systems include as an integral part dose measuring/indicating equipment or software. Establish a Task Group with involvement of professional bodies for the development of a common methodology and harmonized protocols. Join efforts of countries at regional/sub-regional level, to establish regional DRLs for paediatric examinations. Publish numerical values of DRLs in a document/format that can be easily amended when values are updated, and these numbers do not need to be a part of the legislation.</td>
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Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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