Diagnostic reference levels and optimization in radiology: where do we go from here?

To cite this article before publication: Colin J Martin *et al* 2017 *J. Radiol. Prot.* in press https://doi.org/10.1088/1361-6498/aa9cfd

Diagnostic reference levels and optimization in radiology: where do we go from here?

The International Commission on Radiological Protection (ICRP) published a report recently dedicated to the application of diagnostic reference levels (DRLs) in medical imaging, giving guidance on how DRLs might be set and how they can be used in healthcare facilities (ICRP 2017). DRLs have been applied in the UK for over 20 years, and have been instrumental in keeping radiation dose levels for diagnostic examinations at a reasonable level. But they have not been applied widely across the globe until recent times. So, what is a DRL and how does it work? It is a form of dose investigation level against which hospitals can compare patient radiation dose data for diagnostic and interventional procedures at their hospital. As such, it is a tool to aid in identification of facilities or examinations on which efforts in optimization of protection should be targeted. It is applied to the dose level for groups of patients (usually the median dose for the group), but not to individuals. DRLs are set in terms of quantities that are easily measured and assess the amount of ionising radiation used to perform a medical imaging procedure at a hospital. ICRP recommend that national DRLs are set at the 75th percentile of the distribution of median values for DRL quantities for specific examinations at individual facilities across a country. When two imaging modalities are involved in the same procedure (e.g. PET-CT, SPECT-CT), then DRL values for each modality should be set independently. Since data for large numbers of patients in electronic form are available from radiology information systems or through use of patient dose management software, the medians of complete dose distributions are considered to provide a good reflections of typical doses. However, if numbers are limited, then it may be necessary to place restrictions on data based on patient weight. Surveys of DRL quantities in hospitals across a country are required in order to establish national DRLs. Such surveys should be representative of practice in the country where the DRLs are to be applied, as the examinations performed more frequently and the sizes of individuals in the population vary in different countries. Since DRLs are derived from aggregated dose data used to obtain images that radiologists have deemed acceptable for diagnosis, the dose levels can be regarded as values that should be achievable in any facility. DRL values will inevitably be dependent on the state of practice and the available technology at the point in time when they were derived, so national DRL values need to be revised at regular intervals (3-5 years according to ICRP recommendations).

Assessments of dose levels from medical X-rays began as early as the 1950s, and in the 1970s and 1980s extensive surveys of patient doses were performed in the USA by the Nationwide Evaluation of X-ray Trends (NEXT) through the Food and Drug Administration and in the UK by the National Radiological Protection Board (NRPB, now Public Health England). The surveys revealed substantial differences in dose levels across both countries, and the knowledge gained was used in making recommendations about optimization of radiographic technique. The fact that there were large

variations in dose levels highlighted the need for a method of identifying hospitals in which practices were poor or at least not optimized. Therefore the NRPB derived reference doses based on the 75th percentile of the distribution of mean dose levels for a selection of radiographic examinations from the hospitals surveyed (Shrimpton et al 1989). This marked the start of the journey of optimization in radiology for the UK. The ICRP supported the DRL concept in their 1990 recommendations and formally introduced the term DRL in 1996 (ICRP 1996). The European Union (EU) took the early lead in promotion of DRLs through the Council Directive 97/43/EURATOM (EU 1997) and guidance from the European Commission (EC 1999). Member States of the European Union were obligated to promote the establishment and use of DRLs as a strategy for optimization, and this has since been further reinforced in the European Basic Safety Standards (EU 2014). In the intervening years, the use of CT scanning increased steadily across Europe and America, and surveys of CT doses again revealed wide variations in practice and from the results of the UK survey reference dose quantities and initial CT DRLs were developed (Shrimpton et al, 1998). Doses to patients from CT scanning now make up more than half of the dose to the population from medical exposures. In addition, the introduction of digital radiography, which has offered greater opportunities for optimization, removed the close link between the appearance of the image and radiation dose, meaning that the delivery of higher dose levels could go unrecognised if attention was not paid to the exposure level, increasing the need for a link with a measure of dose such as the DRL.

The use of DRLs has subsequently expanded across Europe with 72% of the 36 European countries having DRLs for adult X-ray examinations by 2014, 77 % of which were based at least in part on national dose surveys performed within the country (EC 2014). The National Council for Radiation Protection and Measurements (NCRP) has defined DRLs for the USA based on survey data from the American College of Radiology (NCRP 2012, Bhargavan-Chatfield and Morin 2013) and NEXT. The setting of DRLs for paediatric X-ray examinations has proved more difficult, because of the wide variation in size, but weight groupings for data collection are recommended in ICRP 135 to facilitate this (ICRP 2017). DRLs in nuclear medicine are set in terms of administered activity for each radiopharmaceutical, but tend to be used more as guiding values. Specific activity levels are widely used for adult patients, which does not encourage optimization, and ICRP recommend adjustment of activities to take account of patient weight.

The setting of DRLs in diagnostic radiology is only the first step in a long journey. DRLs help to identify facilities where optimization of protection is required. If the median dose from a survey in a hospital exceeds a DRL, a local review of procedures and equipment should be undertaken to determine whether the protection has been optimized, and action taken to address any deficiencies. This requires staff with relevant knowledge and expertise who can recommend and make the changes. In

the UK, medical physicists working in radiation protection and carrying out performance tests on X-ray equipment, drove the process forward. Medical Physics Experts (MPEs) have the scientific and technological expertise and so have coordinated surveys of patient doses. They have been able to provide the dosimetry information to link with knowledge of the clinical image quality requirements, or "diagnostic information" when several images are used, from radiographers and radiologists to determine the correct balance for optimization of protection. Moreover, medical physics services within the UK are provided on a regional basis by groups of MPEs in larger hospitals, so DRLs have helped to identify the X-ray facilities within each region that delivered higher doses, on which optimization efforts could be focussed.

Therefore, DRLs have been a valuable tool in the UK, but can they work in other countries with different structures? The number of MPEs with expertise in diagnostic radiology in many countries is limited, and if there is no-one else able to take on the mantle, the process may hit a buffer of inactivity preventing further progress on the journey. Countries that are trying to implement optimization for diagnostic radiology examinations comment that, as well as a lack of DRLs, insufficient action is taken to optimize protection. They also comment on difficulties in the optimization of procedures due to lack of personnel with knowledge of dose levels and international guidance. Training for MPEs and others is required, and the International Atomic Energy Agency is supporting programmes in various parts of the world to provide training and assistance with patient dosimetry surveys, performance testing of X-ray equipment, and setting of DRLs to address this need. An aspect that affects proper implementation of the optimization process is the pattern of MPE support (Martin et al 2013). In many parts of Europe there are strong hospital based MPE services, in some parts of the world these services are provided by private companies, while in others no MPEs work in diagnostic radiology. It is expected that the new Directive (EU 2014) will improve this situation in the European Union, through Article 58 that states "in radiodiagnostic and interventional radiology practices involving high doses, a medical physics expert shall be involved". In some parts of the world, government employees perform tests on X-ray equipment and their link with the day to day service is often tenuous. Many patient dose surveys by University Departments have been reported in the literature, but by individuals who may not have the close contact with hospital services required to carry the optimization process forward. In parts of the world where there are few diagnostic radiology MPEs, the professional group in the best position to take optimization forward are radiographers, but they are less likely to have the depth of scientific knowledge required and may not be given time to undertake the necessary surveys of patient doses. The main requirement for undertaking optimization is having staff, especially MPEs with the necessary relevant expertise and the different groups, MPEs, radiographers and radiologists working together. Patient dose surveys take time, but these should become simpler to perform, as

patient dose data become more readily available in radiation dose structured reports and patient dose management software, but collation at national levels will be required to enable DRLs to be set and updated to ensure they continue to represent current practices (EC 2014, Järvinen et al 2017). This and the organisation and staffing of optimization programmes, all call for funds, so need the commitment of governments and the stipulation of requirements in regulations.

Thus in conclusion, it can be said that DRLs provide a good way of identifying X-ray facilities and/or procedures (for certain clinical tasks) where further optimization of protection is required. The growth of patient dose management software, making dose information more readily available can assist in this process of patient dose analysis and optimization. However, DRLs can only be used successfully where there are programmes to collate patient dose data that include regular reviews of the values, and there are sufficient staff with the necessary knowledge and expertise who are given responsibility to carry the optimization process forward. ICRP publication 135 sets out guidance on processes through which DRLs are set, including interventional procedures (and the impact of their complexity) with advice on the numbers of X-ray facilities, examinations, and patients that might be required in a variety of circumstances. It also provides guidance on factors to consider when the median dose for an examination in a hospital exceeds a DRL in order to optimize the protection because, without this step, the whole point of establishing DRLs is lost. Thus the setting of DRLs is the first step in a journey. Unless MPEs and other staff are given the responsibility of taking the optimization process forward, and provided with the necessary education and training, it will not be possible to optimize patient dose levels across the globe.

Colin J Martin

Honorary clinical senior lecturer, University of Glasgow, Scotland, UK

Eliseo Vano

Emeritus Professor at the Faculty of Medicine, Complutense University, Madrid, Spain

ORCID iDs

C J Martin https://orcid.org/0000-0002-0784-9002

E Vano https://orcid.org/0000-0002-1730-1358

References

Bhargavan-Chatfield M and Morin RL 2013 The ACR Computed Tomography Dose Index Registry: the 5 million examination update. J Am Coll Radiol 10(12) 980–983.

EC 1999 Guidance on Diagnostic Reference Levels (DRLs) for Medical Exposures, Radiation Protection 109.

EC 2014 Diagnostic Reference Levels in Thirty-six European Countries. Radiation Protection 180, Part 2/2. (EU Publications Office, Luxembourg).

EU 1997 Council Directive (97/43/Euratom) laying down measures on health protection of individuals against the dangers of ionising radiation in relation to medical exposure. Official Journal of the European Communities, No.L180 (1997).

EU2014 Council Directive (Euratom 2013/59) laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation. Official Journal of the European Communities, No.L13. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2014:013:0001:0073:EN:PDF

ICRP 1996. Radiological Protection and Safety in Medicine, Ch 5 Optimisation of protection, ICRP Publication 73, Ann. ICRP 26 (2).

ICRP 2001 Radiation and your patient: A guide for medical practitioners ICRP Supporting Guidance 2. Diagnostic reference levels in medical imaging: Review and additional advice. Annals of ICRP 31(4).

ICRP 2017 Diagnostic Reference Levels in Medical Imaging. .Publication 135, Annals of ICRP 46(1).

Järvinen, H, Vassileva, J, Samei, E, Wallace, A, Vano, E and Rehani, M 2017 Patient dose monitoring and the use of diagnostic reference levels for the optimization of protection in medical imaging: current status and challenges worldwide. J. Med. Imaging, 4(3), 031214. doi:10.1117/1.JMI.4.3.031214.

Martin, C J, Le Heron, J, Borrás, C, Sookpeng, S and Ramirez, G 2013 Approaches to aspects of optimisation of protection in diagnostic radiology in six continents. J. Radiol.Prot. 33, 711-734.

NCRP 2012. Reference levels and achievable doses in medical and dental imaging: recommendations for the United States, Report No. 172. Bethesda, Md: NCRP.

Shrimpton PC, Wall BF and Hillier MC 1989. Suggested guideline doses for medical X-ray examinations. Radiation Protection – Theory and Practice. Proceedings of 4th International Symposium of the Society for Radiological Protection, June 1989 (Ed EP Goldfinch). Institute of Physics, Bristol, pp85–88.

Shrimpton PC, Jessen KA, Geleijns J, Panzer W and Tosi G 1998 Reference doses in computed tomography. Radiat Prot Dosim, 80(1–3), 55–59.