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Compliance to Diagnostic Reference Levels for radiation exposure in common radiological procedures in Dutch hospitals: A nation-wide survey carried out by medical imaging students

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ABSTRACT

Introduction: In the Netherlands, hospitals have difficulty in implementing the formal procedure of comparing radiation dose values to Diagnostic Reference Levels (DRLs).
Methods: To support the hospitals, train radiography students, and carry out a nationwide dose survey, diagnostic radiography students performed 125 DRL comparisons for nine different procedures in 29 radiology departments. Students were instructed at three Dutch Universities of Applied Sciences with a radiography programme and supervised by medical physicists from the participating hospitals.
Results: After a pilot study in the western part of the country in eight hospitals, this study was enlarged to involve 21 hospitals from all over the Netherlands. The 86 obtained dose comparisons fall below the DRLs in 97% of all cases. This very high compliance may have been enhanced by the voluntary participation of hospitals that are confident about their performance.
Conclusion: The results indicate that the current DRLs that were not based on a national survey, may need to be updated, sometimes to half their current value. For chest and pelvis examinations the DRLs could be lowered from 12 and 300 $\mu Gy \cdot m^2$ to the 75-percentile values found in this study of 5,9 and 188 $\mu Gy \cdot m^2$, respectively.

Introduction

In the Netherlands Diagnostic Reference Levels (DRLs) for radiation exposure were defined in 2012 for 11 common radiological procedures. These procedures include mammography, chest radiography, pelvis radiography, CT pulmonary angiography (CTPA), CT coronary angiography (CTCA), CT abdomen, coronary angiography (CAG) and for children: chest radiography, abdomen radiography, CT head and voiding cystourethrography VCUG.[1] The values of these DRLs have been based on expert judgement and international literature, but not on a nationwide survey. In addition to these DRLs, so-called target values have been set at usually half the value of the DRL. These target values have also been based on expert judgement and they indicate an achievable dose level. Adherence to DRLs is an indication of good radiological practice, in which radiological protection is considered important. Average dose values for groups of patients subject to the same procedure should generally remain below the DRL.[2]

A study by the National Institute for Public Health and the Environment in the Netherlands[3] showed that radiological departments in many hospitals do not compare their dose estimates to the DRLs according to the procedure that was outlined in the national guideline.[1] According to this procedure dose values and weights should be recorded for all procedures except mammography for a minimum of 20 patients. Per procedure the 20 (or more) dose estimates (DAP values for plain and fluoroscopic examinations and CTDIvol and DLP values for CT-scans) should be plotted on a graph against the weights of the patients. A best regression line then needs to be calculated in order to derive a dose estimate for a

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standard patient of 77 kg. It is this dose estimate that should be compared to the DRL and to the target dose value. An example is shown in Fig. 1.

In many cases hospitals in the Netherlands record dose values and compare the averages to the corresponding DRLs. However, weights of patients are not commonly recorded and some (mainly paediatric) procedures are not performed often enough to follow the guideline and gather dose estimates from at least 20 patients. The Ministry of Health, Welfare and Sports acknowledged that it was difficult for radiological departments to comply with the prescribed procedure and looked for ways to support hospitals. The National Institute for Public Health and the Environment that is formally part of the ministry contacted Inholland University (InhU) of Applied Sciences (Haarlem) and a plan was drafted that involved students of the Bachelor programme Medical Imaging and Radiation Oncology carrying out the formal DRL comparison procedure in the hospitals where they receive their training.

The purpose of this study was to assist hospitals in complying to the DRL-procedure, to gather national dose data (and measure DRL compliance) and to provide a means for medical imaging students to get hands-on experience with DRL-procedures.

Methods

In 2014 a pilot study was conducted in which eight hospitals in the western part of the country voluntarily participated.[4] Medical physicists and senior radiographers at these hospitals were contacted and asked to provide local supervision over the students and their measurements. Students participated in this study as a part of their internship, which takes place in their third year of study. Participating diagnostic radiography students received a training at InhU and conducted dose and weight measurements at 'their' hospitals for at least 20 patients for one or more procedures. All patient data was rendered anonymous and therefore ethical approval was not needed. Procedure selection was based on the student's experience and the frequency of procedures in the time frame of the student's internship. The entire examination (and not only the dose and weight measurements) was carried out by the student. Linear regression lines were calculated to estimate the dose value at 77 kg which was then compared to the DRLs and target values. The measurement data were undersigned by the responsible medical physicist and sent to the lead institution (InhU) for further processing. At InhU the results were checked by recalculating the estimate by linear regression as well as a fit of an exponential function. The results were shared anonymously with the National Institute for Public Health and the Environment, who published them on its website for medical radiation applications (www.rivm.nl/ims, in Dutch).

For all adult procedures dose values and weights of a minimum of 20 patients were recorded. Selection of patients was based on a convenience sampling approach by collecting data of all patients in daily routine until a minimum of 20 was obtained. Patient weights were collected at the moment of the radiological procedure. For x-ray procedures DAP values were recorded and CTDIvol and DLP for CT. Dose estimates were plotted against weights and linear and exponential regressions were calculated using Microsoft Excel 2010 software including determination of coefficient R^2 and standard error (SE). In this way a dose value for a patient weight of 77 kg was estimated.

For paediatric x-ray procedures DRLs and target values are defined for age groups neonate, 1 year, and 5 year. For paediatric CT procedures DRLs and target values are defined for age groups neonate, 1 year, 5 year, and 10 year.[1] The arithmetic mean dose value in an age group was compared to the respective DRL and target value.

Mammography mean glandular doses (MGD) were measured at PMMA phantom thickness of 3 cm, 5 cm and 7 cm for comparison to the DRL and target values.

The 2014 pilot study showed the feasibility of the approach, but only eight out of a total of approximately 80 Dutch hospital conglomerates participated. To obtain a larger sample and a more complete view of Dutch clinical practice, the two other Dutch Universities of Applied Sciences with the same bachelor program were involved in 2015: Fontys University of Applied Sciences (Eindhoven) and Hanze University of Applied Sciences (Groningen). The experiences of the 2014 pilot were shared and in 2015 a nationwide study was set up in the same way as the original pilot.[5] In total 21 hospitals from all over the country participated. Again, participation was on a voluntary basis and under supervision of the local medical physicist. Diagnostic radiography students of the three universities performed dose and weight measurements for procedures in the hospitals where they received their clinical training. Selection of procedures, data collection and data processing was similar to the 2014 study. DRL comparisons were excluded if the number of patients was less than 20.

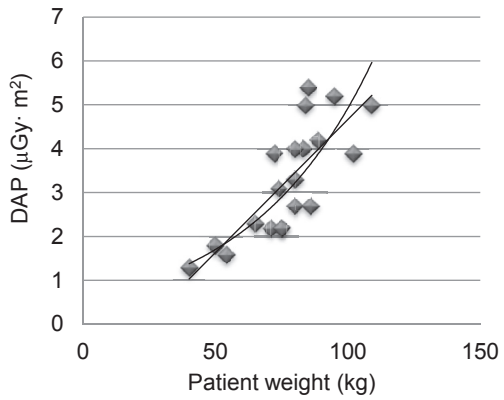

Figure 1. Graph of Dose Area Product (DAP) values against patient weights for chest x-rays (posterior–anterior) in one of the hospitals that participated in the pilot study. The DRL has been set at 12 μGy·m^2 and is therefore off the scale of the figure. Both linear and exponential regression lines are shown. The interpolated DAP at 77 kg is approximately 3 μGy·m^2 and hence about 25% of the DRL.

Results

In the pilot study of 2014 eight hospitals in the western part of the Netherlands participated. Seven of these were willing to share their results. One hospital participated in the study for training purposes, but did not want to make public any results regardless of the outcome. In Fig. 1 a typical example of a comparison of dose values to the DRL is shown for chest examinations in one of the participating hospitals. The DRL comparison procedure requires an estimation of the dose value for a patient of 77 kg. This can either be derived by linear or exponential regression of the collected data. As shown in Fig. 1, the difference between these two is marginal, especially when compared to the DRL of 12 μGy·m^2.

In 2014, dose values for eight different radiological procedures (out of 11 for which national DRLs have been defined) were compared to DRLs (see Table 1). Some procedures were compared in all hospitals and sometimes in more than one x-ray room. Other procedures were compared only sporadically, due to the limited availability of patients. The three procedures for which no comparison to the DRL could be performed were all for children: abdomen examination, CT head and VCUG. The hospitals that participated did not receive enough children during the

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