Diagnostic Reference Levels (DRLs) in projection radiography

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Introduction

Standard radiology procedures in projection radiography (plain film or digital equipment) account for 48% of the total number of examinations in diagnostic radiology and contribute 41% to the collective dose [1]. This implies that justification and optimization is not only important for high-dose applications like computed tomography or fluoroscopy but also for projection radiography. One of the main targets with the introduction of the DRL concept is to investigate situations, where patient doses are unusually high. Thus, DRLs provide a valuable method for dose optimization processes [2]. With the aim to establish and 'familiarize' the published reference levels and to customize them into national DRLs, a nationwide survey of applied patient dose in projection radiography was performed. The complete analysis of the study will be compared with an international compilation of DRLs in common radiography [3].

Material and Methods

The quantity of interest in routine measurements of the patient dose in projection radiography is the Entrance Surface Dose (ESD). 38 hospital radiology departments evenly distributed across Switzerland were involved in the survey. Because plain film radiography has fully been replaced by digital radiography systems, the scope of the units was limited to non film-screen equipment (CR or DR). – For each institute, three types of common radiographs were evaluated (chest, lumbar spine and pelvis in ap or pa projection). The geographic allocation is represented as follows: 24 of the participating institutes are located in the german speaking part, 11 in the french speaking part and 3 institutes in the italian speaking part of Switzerland.

For the determination of the Entrance Surface Dose on the table (ESD_{Table}), a calibrated X-ray multimeter (Barracuda, RTI Electronics, Mölndal, Sweden), equipped with a solid state detector (R-100B) was used.
First, the local tube output K_L of the unit was calculated by measuring the ESD_{Table}, using the equation (1). Thereafter, using the equation (2), the ESD was calculated for standard patients by applying the calculated local tube output, the used exposition parameters tube voltage, tube current and focus-skin-distance, and a well accepted backscatter factor (BSF) of 1.35 [1, 5].

$$(1) \qquad K_L = ESD_{Table} \cdot \left(\frac{100}{U}\right)^2 \cdot \left(\frac{1}{Q}\right) \cdot FDD^2 \cdot \left(\frac{1}{f}\right)$$

$$(2) \qquad ESD = K_L \cdot \left(\frac{U}{100}\right)^2 \cdot Q \cdot \left(\frac{1}{FOD}\right)^2 \cdot BSF$$

K_L = characteristic constant of the tube (tube output), including filtration [mGy·m^2·mAs^{-1}]
U = tube voltage [kV]
Q = tube current [mAs]
FOD = focus-skin-distance [m]
FDD = focus-detector-distance [m]
BSF = backscatter factor (1.35)
f = intrinsic scatter factor of solid state detector (1.15)

The distribution of the ESD values (mean, minimum, maximum, 25th percentile, 75th percentile) was calculated for each unit and examination and compared to the current published DRLs, which are based on the European directive [4, 6]. National DRLs will subsequently be adapted, if necessary.

Results

An overall data amount of total 38 institutes was analysed. The final results showed that the derived ESD values are far below the existing DRLs (*Fig. 1*). For the chest region, the 75th percentile of the ESD distribution amounts 0.16 mGy (53.3% of the DRL which is 0.3 mGy). For the pelvis, the calculated 75th percentile of the ESD distribution is 3.19 mGy (31.9% of 10 mGy) and the lumbar spine shows a 75th percentile of 6.58 mGy (65.8% of 10 mGy).

Chest (n=425)

Mean	Median	1st quartile	3rd quartile
0.12	0.11	0.07	0.16
Min	Max		DRL
0.02	0.55		0.30

Pelvis (n=399)

Mean	Median	1st quartile	3rd quartile
2.34	1.95	1.22	3.19
Min	Max		DRL
0.07	8.52		10.00

Lumbar Spine (n=378)

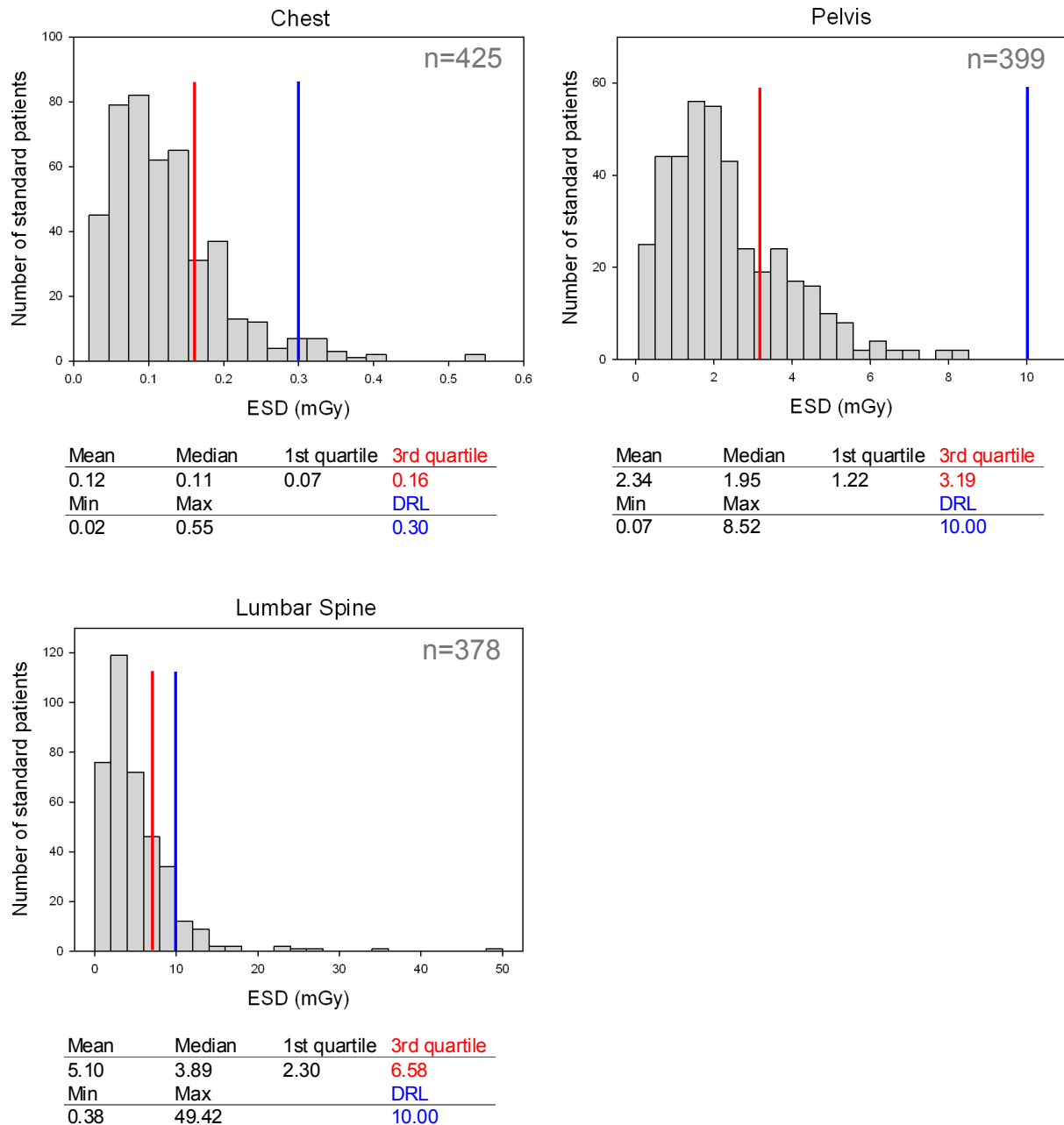| Mean	Median	1st quartile	3rd quartile
5.10	3.89	2.30	6.58
Min	Max		DRL
0.38	49.42		10.00

Fig. 1. Statistics of the three explored organ regions. The existing DRLs and the 75th percentiles of the study are represented by blue and red vertical lines, respectively.
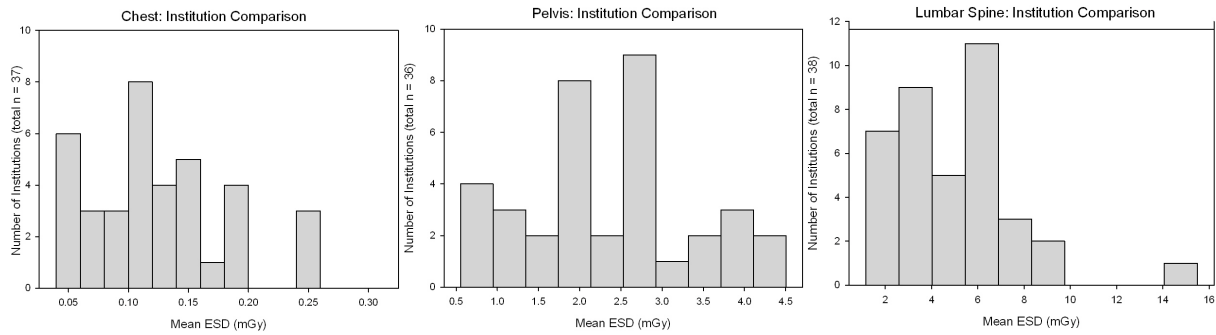
Fig. 2. Distribution histograms of the mean ESD values (institution comparison)

In the institution comparison *(Fig. 2)* a wide distribution of the mean ESD values was observed for all three organ regions (chest 0.05-0.25 mGy, pelvis 0.5-4.5 mGy, lumbar spine 1-15 mGy).

A combined illustration of both the inter-institutional comparison betweeen CR and DR image receptor systems and the ranking of the calculated mean ESD values of all institutions is shown in *Fig. 3.* It is obvious, that the majority of the DR-systems (green bars) are in a significant lower dose range than the CR receptors (blue bars). The reason for this is based on the intrinsic lower dose requirements of DR-systems as a result of the higher detective quantum efficiency (DQE).

Discussion

The results showed a significant potential of reducing entrance surface doses for patients in typical diagnostic imaging situations.

One of the reasons for the remarkably lower values of the 75th percentiles in this survey (compared to the existing DRLs) is explained by the high optimization potential of digital imaging modalities (particularly with direct radiography systems as mentioned above). In several places an optimization of the image receptor doses (K_B-values) was recommended. This request can be achieved by adapting the local AEC switch-off doses (organ-related automatic exposure control) of the unit.

According to the actual analysis, the present results will allow to reduce the national diagnostic reference levels significantly (approximately by a factor 1.5-2 for chest and lumbar spine and even by a factor of 3 for pelvis). To validate the results for the other organ regions where DRLs have been published, an additional small study was launched (including chest lateral and lumbar spine lateral).
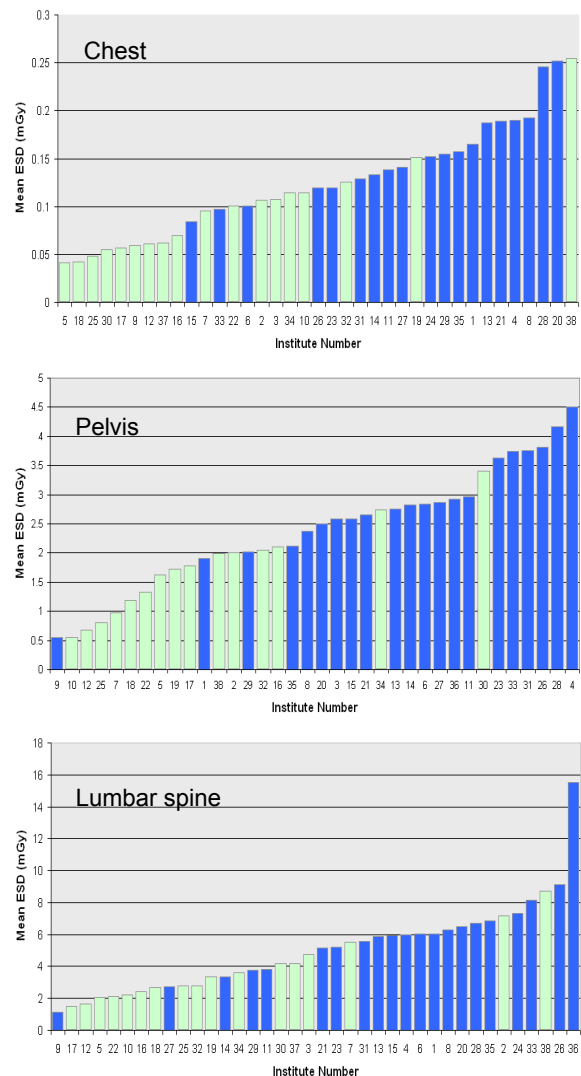

Fig. 3. Ranking and CR/DR comparison
blue: CR-systems
computed radiography (storage plates)
green: DR-systems
direct radiography systems (flatpanel detectors)

The main objective of optimization procedures is to achieve diagnostic image quality using appropriate patient doses (according to ALARA). The introduction of new techniques should involve radiologists, medical physicists and radiographers to establish QA- and dose management programmes.

The survey has shown that DRLs can act as effective comparison indicators for patient dose management in the field of projection radiography, helping to avoid unnecessary high doses.

References

[1] Aroua A.; Vader J.P.; Valley J.F.: A survey on exposure by radiodiagnostics in Switzerland in 1998. Lausanne IRA/IMSMP (2000), pp. 44-45.

[2] Guidance on the Establishment and Use of Diagnostic Reference Levels for Medical X-Ray Examinations. IPEM Report 88. York UK (2004).

[3] Hart D.; Hillier M.C.; Wall B.F.: National reference doses for common radiographic, fluoroscopic and dental X-ray examinations in the UK. BJR, (January 2009), Table 7, p. 11.

[4] BAG-Weisung R-06-04: Diagnostische Referenzwerte (DRW) in der Radiologie. Bern, BAG (2006)

[5] Roth J.; Strahlenschutz in der Medizin. 1. Aufl., Bern, Verlag Hans Huber (2008) p. 43.

[6] European Commission; Radiation protection 109, Guidance on diagnostic reference levels (DRLs) for medical exposures. Luxembourg (1999).