National collection of local diagnostic reference levels in Norway and their role in optimization of X-ray examinations

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Abstract. The concept of diagnostic reference levels (DRLs) is recognised as an efficient and powerful tool in optimization of diagnostic X-ray examinations. Norway was one of the pioneer countries in establishing national DRLs, but focus on implementation and use of DRLs locally at the clinics in optimization purposes has been absent until now. The aim of this study was to map the dose levels and optimization potentials by carrying out a national collection of local DRLs. Totally 40 health care enterprises (HCEs) representing 104 individual clinics were asked to report local DRLs for eleven conventional X-ray examinations (including mammography) and nine CT-examinations. The response rate from the clinics was 69% and resulted in 539 individual reported local DRLs in total. Large variations in local DRLs were observed between different clinics for all examination types, ranging from a factor of 3.3 to 61 for conventional coronary angiography and lumbar spine, respectively. Local DRLs exceeding the current national DRLs were observed for all examination types except for conventional coronary angiography. The 75th percentile of the collected local DRLs indicates a need for a downward revision of the national DRLs by 20-60%. A recalculation of the collective effective dose (CED) of 1.1 mSv from 2002 based on the updated dose data resulted in a reduction of the CED by 17%. The impact on patient dose by replacing some conventional X-ray examinations (urography, colon, coronary angiography) with CT-examinations is also briefly discussed.

KEYWORDS: Diagnostic reference levels (DRLs), optimization, patient doses, X-ray examinations.

1. Introduction

Radiological examinations are the largest man-made source to collective effective dose (CED) in Norway and contributed to 1.1 mSv per inhabitant in 2002 [1-2]. National surveys on examination frequencies and patient doses have shown an increase in the CED by as much as 40% from 1993 to 2002 and are mainly due to the rapid growth in the availability of CT-scanners [2-4]. In 2002 CT-examinations accounted for as much as 60% of the CED but only 12% of the total number of radiological examinations, while the corresponding numbers from 1993 were 30% and 7%, respectively. Implementation and use of diagnostic reference levels (DRLs) is recognised as an efficient and powerful tool in optimization of diagnostic X-ray examinations [5-7]. The dose-reducing potential of focusing on establishment of local DRLs, continuous optimization of examination protocols and successive downward revising of national DRLs has been shown by the National Radiological Protection Board (NRPB, now a part of the Health Protection Agency) [8-9]. Dose surveys carried out in the United Kingdom (UK) showed a reduction in patient dose by almost 50% from both conventional X-ray examinations (1985-2000) and CT-examinations (1991-2003) [10-15]. The CED in UK has pretty much remained constant in the time period from 1985 to 2001 with only a 25% increase, despite an increase in total number of performed radiological examinations [16-17]. The CED per caput from medical X-ray examinations in UK in 2001 was 0.38 mSv (including dental X-ray examinations) where CT-examinations accounted for 47% of the total dose. UK holds the lowest CED per inhabitant in Europe and is almost a factor 3 lower then the CED in Norway from 2002.

The large difference in CED between Norway and UK is really a paradox, since Norway was one of the pioneer countries in establishing national DRLs, as proposed by the ICRP [18]. Common Nordic DRLs, mainly based on the Norwegian dose survey performed in 1987, was published for six conventional radiological examinations in 1996 [3, 19-20]. The concept of DRLs was later adopted by the European Commission and introduced in the Medical Patient Directive in 1997 [21]. All member countries were herby committed to implement this requirement in their national regulations by the year 2000. As a non-member country, Norway first introduced the concept of DRLs in their national regulation in 2004 and published national DRLs for six conventional X-ray examinations, five CT examinations and two mammography examinations (screening and clinical) in 2005 [22-23]. It has to

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be emphasized that four of the six national DRLs for conventional X-ray examinations are still based on dose data from 1987. As a consequence, these national DRLs do not reflect the digital environment present in almost all Norwegian hospitals and X-ray institutes nowadays. Similarly, the national DRLs for CT-examinations do not reflect the enormous development within CT scanner technology, which has resulted in a replacement of almost all the old single slice scanners with powerful multi slice scanners capable of giving up to 64 simultaneous slices per rotation. The national DRLs for mammography were revised in 2007 and are the only national DRLs reflecting the current technology and radiological practice [24]. The lack of updated dose data has probably resulted in an overestimation of the CED of 1.1 mSv from 2002.

A pilot study was carried out in 2006, collecting local DRLs from Health Care Enterprises (HCEs) within Health Region East (resulting in 160 individual local DRLs from totally 11 HCEs) [25]. Few HCEs had established their local DRLs prior to this collection and therefore had to establish them in a relative limited time period. Not surprisingly, this pilot study revealed large variations in local DRLs between HCEs and addressed the need for optimization of radiological examinations with respect to patient doses. The 75^{th} percentile from the collected doses also indicated that the current national DRLs could be lowered for most of the examinations. Based on the results observed in this pilot study the Norwegian Radiation Protection Authority (NRPA) initiated a national collection of local DRLs from all HCEs in Norway in 2007. The aim of this study was to map the national dose levels and optimization potentials for a number of radiological examinations and to revise the national DRLs to reflect equipment technology and radiological practise of today. Focusing on DRLs locally at every HCE will result in more optimized and standardized examination protocols and hopefully also to a reduced contribution from medical exposure to the CED.

2. Material and methods

All private and public Health Care Enterprises (HCEs) approved for radiological examination performance were asked to report their local DRLs to NRPA during spring 2008. In an attempt to improve the response rate, the HCEs were given a time limit of five months, making it possible to establish the local DRLs if not already completed. NRPA also prepared a national guideline on how to establish local DRLs for radiological examinations and this guideline was distributed to all HCEs prior to the collection of national doses [24]. In addition, a briefing meeting with the radiation protection officers (RPOs) at the HCEs were held to prepare them for the forthcoming reporting on local DRLs.

The local DRLs presented in this study are based on the mean value of dose measurements from ideally 20 patients reflecting both sexes. Local DRLs based on a minimum of 10 patients were also accepted. Individual patient weights under 55 kg and over 90 kg were excluded from the data material. For mammography, all breast thicknesses were included but those having breast implants were excluded. The local DRLs were derived from one specific examination room and not from a mixture of different rooms. The examinations were defined only in general clinical purposes with a minimum of specification of clinical indication and technical factors related to the examination protocol.

The dosimetric quantities used for establishing the local DRLs were all based on easily available dose parameters provided by the X-ray equipment after ended examination. For conventional X-ray examinations (radiographic and fluoroscopic) the dose-area product (DAP) was used and for CT-examinations both the volume computed tomography dose index ($CTDI_{vol}$) and dose-length product (DLP) were used. The average glandular dose (AGD) was used as the dose parameter for mammography examinations. For conventional X-ray equipment that could not provide the requested dose parameter, a portable DAP-meter was used to measure the DAP. For mammography the AGD was calculated from the measured air kerma at the entrance of the breast by applying a conversion factor which is dependent on the characteristic properties of the breast (thickness and amount of glandular tissue) and the radiation quality used [26]. No DRLs were reported from CT-scanners that don't provide any dose parameters. To ensure reliable dose data, the dose parameters provided by the X-ray equipment or measuring device must be properly calibrated prior to the establishment of the local DRLs. This calibration should be traceable to a secondary standard dosimetry laboratory (SSDL) [27].

All radiological examinations, for which national DRLs were established, were subjected to reporting together with some additional examinations in an attempt to establish new national DRLs. All HCEs were asked to report local DRLs on all examinations that were frequently performed at their hospitals and X-ray institutes. Conventional X-ray examinations (both radiographic and fluoroscopic) associated with a national DRL were examinations of the thorax, lumbar spine, pelvis, colon (double contrast), urography, coronary angiography and mammography (both clinical and screening). CT-examinations associated with national DRLs were examinations of the caput, thorax, high resolution thorax, lumbar spine and abdomen (including pelvis). The included conventional X-ray examinations without national DRLs were acute abdomen, under-extremity angiography and abdominal stent graft. For CT, virtual colonoscopy, coronary angiography, urography and pelvis were the included examinations. Doses from screening mammography had already been collected from all screening units during 2006-2008 as a part of their quality control program. These doses were used in this study to establish local DRLs for screening mammography.

The local DRLs were collected by means of a questionnaire. Patient data (age, sex, weight and height) and dose measurements for all the individual 20 patients were reported together with information about the calibration of the dose measuring device and its traceability. HCEs participating in the 2006 pilot study were not ordered to revise their local DRLs for those examinations already reported for. Local DRLs collected in 2006 were therefore included in this study, if not revised DRLs were received.

The need for revising the existing national DRLs was evaluated from the 75^{th} percentile of all the received local DRLs. To be considered representative for the national radiological practise, the total number of received local DRLs must account for at least 25% of the total national examination volume. The total examination volume was assessed by means of an additional questionnaire distributed to all HCEs. New values of the current national DRLs will be proposed for those examinations where a need for revision was revealed if the quantity of the collected local DRLs were high enough to be representative.

3. Results

Totally 40 private and public Health Care Enterprises (HCEs) representing 104 individual hospitals and X-ray institutes (hereby referred to as clinics) are approved to perform radiological examinations in Norway. The size of each HCE varies from one clinic to ten clinics, with a mean number of 2.7 clinics per HCE. Approximately 87, 32 and 21 of these individual clinics carry out CT-examinations, mammography screening and clinical mammography, respectively. The overall response from the HCEs (after one reminder) was high, giving a response rate of 78%. The majority of those HCEs that consisted of more than one clinic did not report local DRLs from all their clinics. As an average, these HCEs reported local DRLs from 79% of their clinics (range: 33-100%), which give a final response rate from the 104 individual clinics of 69%. The number of local DRLs reported from each HCE varied between one and 44, with a mean number of 16 reported DRLs from each HCE. This large variation is mainly due to the size of the HCEs (i.e. number of clinics), number of different types of examinations performed and the level of implementation of local DRLs. A total of 539 individual local DRLs were received (conventional X-ray: 285, CT: 211, mammography: 43). The majority of the clinics carry out at least six of the conventional X-ray examinations and five of the CT examinations they were asked to report on. With this in mind, the average reporting rate from the clinics was only 50% (20-100%) of the conventional X-ray examinations and 70% (20-100%) of the CT-examinations. Local DRLs for clinical mammography were received from 62% of the clinics, while for screening the doses collected in 2006-2008 represented 94% of the clinics. This indicates that the level of implementation of establishing local DRLs in Norwegian HCEs is far from completed. No local DRLs were received for conventional X-ray examinations of under-extremity angiography and abdominal stent graft and only few local DRLs were received for virtual CT colonoscopy, coronary CT angiography and CT-examinations of pelvis. The most frequent reported examinations were conventional X-ray examinations of thorax, lumbar spine and pelvis together with CT-examinations of caput, thorax and abdomen. All the main vendors were represented in this study, covering a broad range of different equipment technologies and exposure geometries.

Figure 1 illustrates the distribution of the reported local DRLs for conventional X-ray examinations of the lumbar spine together with the mean, 75th percentile and current national DRL. As can be seen, 7 of the reported local DRLs were above the national DRL. Table 1 summarize all the reported local DRLs for conventional X-ray examinations expressed in DAP [Gycm^2], while Table 2 and 3 summarize the reported local DRLs for CT-examinations expressed in $CTDI_{vol}$ [mGy] and DLP [mGycm], respectively. The reported local DRLs for mammography examinations, expressed in AGD [mGy], are summarized in Table 4. The mean weight of all the individual patients was within 70±5 kg, while the maximum and minimum of the mean weight from each reported DRL was within the range of 63-79 kg, except for CT coronary angiography examinations having a mean weight of 85 kg. For mammography, the mean breast thickness of all the individual patients was within 50±5 mm, ranging from 40-65 mm for each reported DRL.

Figure 1: The distribution of the reported local DRLs expressed in DAP [Gycm^2] for conventional X-ray examinations of the lumbar spine. The mean DAP, 75th percentile and current national DRL (NDRL) are also indicated by lines.

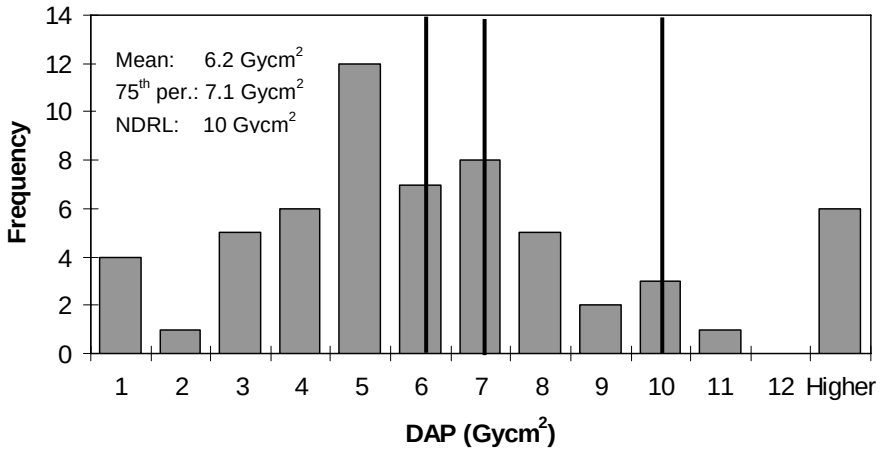


Table 1: Mean local DRLs (LDRL) expressed in DAP [Gycm^2], standard error (SE), standard deviation (SD) and 75th percentile for conventional X-ray examinations. The total number of reported doses with reporting rate given in brackets, mean weight [kg], max./min.-ratio of local DRLs reported from the HCEs together with the max./min.-ratio of reported individual patient doses are also presented together with the current national DRLs (NDRL) and the proposed revised NDRLs (new NDRL).

Examination	No. (%)[a]	Mean weight	Mean LDRL	SE[b]	SD[c] (k=1)	Max/min (HCE)	Max/min (patient)	75th per.	NDRL	New NDRL
Thorax	86 (51)	72	0.46	0.04	0.43	34	211	0.54	0.6	0.6
Urography	18 (27)	72	12	1.7	7.5	14	118	15	20	20
Lumbar spine	60 (35)	71	6.2	0.6	4.3	61	394	7.1	10	7
Pelvis	68 (39)	71	1.8	0.1	1.1	5.4	97	2.4	4	2.5
Colon DC[d]	30 (60)	71	28	3	16	11	82	38	50	40
Coronary angiography	10 (40)	74	39	3	10	3.3	46	34	80	35
Abdomen	13 (14)	70	4.8	0.9	3.2	8	92	5.5	-	-

[a] The reporting rate is estimated by the number of total reported local DRLs divided on the total number of performed examinations.
[b] SE is the standard error in the mean DAP-value from all the reported local DRLs and is defined by SD divided by the square root of the total number of received local DRLs.
[c] SD is the standard deviation of the distribution of the reported local DRLs with a confidence interval of 68.3% (k=1).
[d] Colon Double Contrast.

Table 2: Mean local DRLs (LDRL) expressed in $CTDI_{vol}$ [mGy], standard error (SE), standard deviation (SD) and 75th percentile for CT-examinations. The total number of reported doses with reporting rate given in brackets, mean weight [kg], max./min.-ratio of local DRLs reported from the HCEs together with the max./min.-ratio of reported individual patient doses are also presented together with the current national DRLs (NDRL) and the proposed revised national DRLs (new NDRL).

Examination	No. (%)[a]	Mean weight	Mean LDRL	SE[b]	SD[c] (k=1)	Max/min (HEC)	Max/min (patient)	75th per.	NDRL	New NDRL
Caput	56 (52)	72	64	3	20	4,9	13	73	75	75
Thorax	44 (42)	71	10	1	4.7	5.9	53	13	20	15
Thorax HR	8 (-)	74	3.4	0.8	2.2	5,4	9.4	5	35	35
Lumbar spine	22 (23)	72	25	2	11	4,6	18	30	55	30
Abdomen	49 (49)	71	13	1	4.1	4.9	24	15	25	15
Urography	15 (16)	73	5.9	0.1	3.8	6.8	15	6.4	-	-
Pelvis	5 (-)	72	18	-	-	-	-	-	-	-
Virtual colonoscopy	2 (7)	74	6.9	-	-	-	-	-	-	-
Coronary angiography	3 (19)	82	75	-	-	-	-	-	-	-

a) The reporting rate is estimated by the number of total reported local DRLs divided on the total number of performed examinations.
b) SE is the standard error in the mean CTDI-value from all the reported local DRLs and is defined by SD divided by the square root of the total number of received local DRLs.
c) SD is the standard deviation of the distribution of the reported local DRLs with a confidence interval of 68.3% (k=1).

Table 3: Mean local DRLs (LDRL) expressed in DLP [mGycm], standard error (SE), standard deviation (SD) and 75th percentile for CT-examinations. The total number of reported doses with reporting rate given in brackets, max./min.-ratio of local DRLs reported from the HCEs together with the max./min.-ratio of reported individual patient doses are also presented together with the current national DRLs (NDRL) and the proposed revised national DRLs (new NDRL). The mean weight of the patient is the same as given in table 2 and not included in this table.

Examination	No. (%)[a]	Mean LDRL	SE[b]	SD[c] (k=1)	Max/min (HCE)	Max/min (patient)	75th per.	NDRL	New NDRL
Caput	60 (56)	866	32	246	3.9	17	1002	1200	1000
Thorax	45 (43)	325	21	139	7.2	39	402	600	400
Thorax HR	7 (-)	78	34	90	30	45	102	280	280
Lumbar spine	21 (23)	347	31	141	3.7	13	400	600	400
Abdomen	49 (49)	590	29	201	6.2	32	713	800	710
Urography	15 (16)	246	44	170	6.7	17	256	-	-
Pelvis	5 (-)	403	-	-	-	-	-	-	-
Virtual colonoscopy	3 (11)	506	-	-	-	-	-	-	-
Coronary angiography	4 (25)	1192	-	-	-	-	-	-	-

a) The reporting rate is estimated by the number of total reported local DRLs divided on the total number of performed examinations.
b) SE is the standard error in the mean DLP-value from all the reported local DRLs and is defined by SD divided by the square root of the total number of received local DRLs.
c) SD is the standard deviation of the distribution of the reported local DRLs with a confidence interval of 68.3% (k=1).

Table 4: Mean local DRLs (LDRL) expressed in AGD [mGy], standard error (SE), standard deviation (SD) and 75th percentile for mammography examinations. The total number of reported doses with reporting rate given in brackets, mean breast thickness (BT) [mm], max./min.-ratio of local DRLs reported from the HCEs together with the max./min.-ratio of reported individual patient doses are also presented together with the current national DRLs (NDRL).

Exam.	No. (%)[a]	Proj.	Mean BT	Mean LDRL	SE[b]	SD[c] (k=1)	Max/min (HCE)	Max/min (patient)	75th per.	NDRL
		Front	49.3	1.14	0.08	0.29	3.3	17	1.35	**1.3**
Clinical	13 (62)	MLO[d]	51.4	1.24	0.09	0.34	3.6	16	1.40	**1.5**
		Total	50.4	2.38	0.17	0.63	3.5	14	2.74	**3.0**
		Front	51.6	1.21	0.05	0.26	3.1	22	1.39	**1.3**
Screening	30 (94)	MLO[d]	52.8	1.30	0.05	0.30	3.3	70	1.49	**1.5**
		Total	52.2	2.52	0.10	0.55	2.8	12	2.89	**3.0**

a) The reporting rate is estimated by the number of total reported local DRLs divided on the total number of performed examinations.
b) SE is the standard error in the mean AGD-value from all the reported local DRLs and is defined by SD divided by the square root of the total number of received local DRLs.
c) SD is the standard deviation of the distribution of the reported local DRLs with a confidence interval of 68.3% (k=1).
d) Medio lateral oblique

Large individual differences in the reported doses for all examination types (both conventional and CT) were observed between the clinics, as illustrated by the large standard deviations of the received dose distributions. Generally, this variation was most pronounced for conventional X-ray examinations and the largest variations was found for thorax examinations were the SD constituted as much as 93% of the mean DAP value. Conventional coronary angiography and CT abdomen were the examination types considered with the lowest variation. The ratio between the maximum and minimum local DRL reported from the clinics were highest for conventional X-ray examinations with a factor ranging from 3.3 for coronary angiography to 61 for lumbar spine examinations. The corresponding ratios from CT-examinations were all within a factor of 10. Variation in individual patient doses was normally huge, ranging from a factor of 46 to 394 for conventional X-ray examinations and 13 to 53 (CTDI) and 13 to 39 (DLP) for CT-examinations. The most extreme variations were patient related (i.e. weight, medical case, etc.), but most of the variation observed were due to the X-ray equipment and exposure protocol in local use. No mentionable differences in the doses reported from clinical and screening mammography were observed when corrected for the mean breast thickness. About 40 % of the HCEs reported on calibration of the DAP-value used in establishment of their local DRLs, while the corresponding number for $CTDI_{vol}$ and DLP were about 30%. Almost all comments on the calibration traceability were imprecise.

Local DRLs exceeding the current national DRLs were observed for all examination types except for conventional coronary angiography. Examination types with more than 10% of the local DRLs exceeding the national DRLs were conventional X-ray examinations of thorax (20%), urography (17%) and lumbar spine (12%) together with CT caput (16%), see Fig. 1. The 75th percentile of the collected local DRLs reflects a need for revision of almost all of the existing national DRLs, with the exception of mammography. For all examinations, except conventional thorax and CT caput, the national DRLs could be lowered by 10 to 60%. Conventional urography and high resolution CT-examination of the thorax received too few local DRLs to justify a revision of the national DRLs. Unfortunately, this was also the case for all the additional examinations not having a national DRL and the goal of establish national DRLs for these examinations failed. Proposed revised national DRLs for conventional X-ray examinations and CT-examinations are given in Tables 1-3.

4. Discussion

The concept of DRLs have for long been recognized as one of the most efficient and practical tools used for optimization of radiological examinations locally at the hospitals [5-7]. The concept of DRLs is beginning to be a well-defined tool in many countries and most countries that have focused on local establishment of DRLs have reported a reduction in patient doses due to optimization [28-30]. It has to be emphasized that to achieve the desired dose reducing effect, establishment of national DRLs in itself is not enough. To succeed, frequent collections of local DRLs followed by a subsequent

downward revise of the national DRLs is needed [31]. As mentioned in the introduction, Norway was one of the pioneer countries in the process of establishing national DRLs. Establishment of local DRLs and corrective actions if they consistently exceed the national DRLs have been made mandatory through the new radiation protection regulation from 2004 [22]. The responsibility of local implementation of this requirement is placed on the HCEs, but NRPA has an important role in the follow up of this requirement in order to obtain the desired dose reducing result.

Guidance on DRLs for medical exposures provided by the European Commission and the institute of physics and engineering in medicine (IPEM) recommend that the local DRLs should be derived for typical examinations based on a minimum of dose measurements from 10 standard-sized patients (i.e. weights not exceeding 70±10 kg) undergoing standard examination procedure [5-6]. The 2006 pilot study revealed that this narrow definition of a standard-sized patient were difficult to deal with in a typical Norwegian hospital, especially if the dose measurements had to be carried out in a limited time period [25]. Data from the Statistic Norway also conclude that 20% of the population (both women and men) are categorised as over weight and further support the acceptance of all patient weights to be included in the data material [32]. The national guidance on DRLs therefore accepts all patients within the weight range 55-90 kg but at the same time also increased the number of individual patients to 20 to get a better statistics. Care has to be taken, by allowing a broader weight group to represent the standard-sized patient it could be difficult to interpret its impact on the observed dose variations between different hospitals. On the other hand, as the mean weight of the patient material lies within 70±5 kg, it is assumed to have a minor effect on the settings of local DRLs [6]. This weight criterion was obtained for almost all of the reported local DRLs for all examination types (75^{th} percentile of all mean patient weights were within 70±5 kg). Excluding those local DRLs based on a higher or lower mean patient weight from the data material, only affected the value of the 75^{th} percentile with maximum ± 3%. A slightly higher effect was observed for those examinations having a reporting rate below 25%. This illustrates that the collected local DRLs mainly reflects patient dose variations not caused by differences in the patient weight. The same argumentation holds for the acceptance of all breast thicknesses.

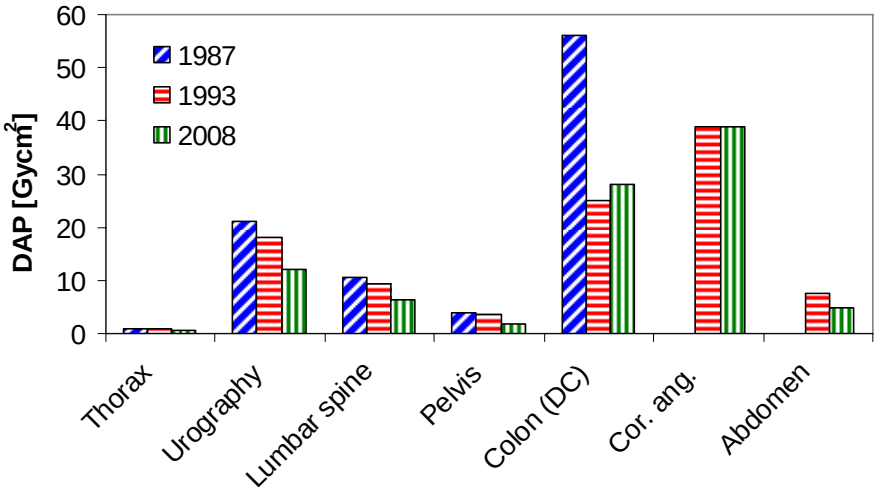
To achieve the best radiological protection of the patient, available resources should be focused on those examination types that contribute most to the national CED. Results from the Norwegian dose survey from 2002 verify that all examination types having a national DRL give a significant contribution to the CED. Conventional urography, lumbar spine and pelvis examinations together with CT caput, CT thorax, CT lumbar spine and CT abdomen could all be found on both the list of top-ten contributors to the CED and on the list of 25 most frequent performed examination types. Conventional thorax examinations and mammography were the two most frequent performed examinations in Norway in 2002 and conventional colon double contrast and abdomen examinations were also among the top-ten contributors to the CED, despite their lower performance frequency. The only examination on both lists without any established national DRL was CT examinations of the pelvis. This was the main reason for including this examination when reporting local DRLs. The rapid development in CT technology will probably lead to CT-examinations replacing conventional X-ray examinations. This is predicted to be the case for colon examinations, urography and coronary angiography. Determine national DRLs for these rapidly increasing CT-examinations will give valuable information of the dose levels and the risks associated with this shift in examination modality. A rough estimation based on the collected doses indicates an increase in the effective dose by a factor of 1.2 to 2.5 by replacing these conventional X-ray examinations with CT-examinations.

This study represents the first national collection of local DRLs and not surprisingly it revealed enormous variations between the different clinics in reported local DRLs and individual patient doses. The reasons for the dose variations are multifactorial, but mainly due to different exposure parameters and radiographic technique. This demonstrates a huge optimization potential within almost every clinic. By putting the available resources to optimize all those examination protocols exceeding the 75^{th} percentile of the collected local DRLs, a considerable reduction in the contribution from medical exposure to the CED could be achieved. The fact that the minority of the HCEs had performed some kind of calibration of the dose parameters used for local DRL establishments, may have some impact on the absolute value of the reported doses. A survey on calibration of DAP-meters carried out among a representative number of HCEs in 2008 concluded that 12% of the DAP-values provided by the X-

ray equipment having overcouch geometry were outside ±10% of the true value [33]. For undercouch geometry the situation was much more dramatic, showing that 71% of the DAP-values were outside ±10% of the true value. The main reason for this large deviation is due to the fact that the couch transmission was not accounted for in the provided DAP-value. The absolute dose value from examinations carried out on X-ray equipment with undercouch geometry may therefore be associated with a relative high uncertainty. The same survey also revealed a low level of local knowledge and skills about DAP calibration. Norway is a country having very few qualified medical physicists working within diagnostic radiology [34]. This situation is now about to change due to the new radiation protection regulations from 2004 [22]. Compared to the situation in the UK, medical physicists are present in almost all radiological departments [17]. It is obvious, that the presence of qualified medical physicists within diagnostic radiology have a positive impact on the optimization of radiological examinations.

A comparison of the mean doses for the Norwegian dose surveys carried out from 1987 to 2008 is shown in Fig 2. As can be seen, a successive reduction of the patient dose has been achieved in Norway for conventional X-ray examinations with the exception of colon double contrast and coronary angiography. This trend was more or less anticipated, not only from the indications revealed in the 2006 pilot survey, but from the knowledge of a total change in the radiological equipment technology. The old film-screen systems are now totally replaced by computed radiology and digital radiology, the latter having detectors with a much higher quantum efficiency compared to the film-screen system. An overexposure on a digital system will not appear as a black film and knowledge of local dose levels and comparison with updated national DRLs are therefore extremely important in the digital environment of today. A recalculation of the estimated CED from 2002, based on the mean patient doses observed in this survey result in reduction of the CED of totally 17%. This emphasise the importance of using updated data for both examination frequencies and dose levels in the estimation of collective effective dose. By focusing on optimization of those examination protocols giving patient doses above the 75th percentile (if not medically justified) it should be feasible to slow down the rapid increase in CED from medical examinations.

Figure 2: Mean doses expressed in DAP [Gycm^2] for the national dose surveys carried out in 1987, 1993 and 2008 for some conventional X-ray examinations [3-4].



5. Conclusion

This study has revealed large dose variations between individual HCEs and clinics which indicate an enormous optimization potential of radiological examination protocols. The collected local DRLs showed a general decrease in patient doses and most of the current national DRLs are proposed lowered by 10-60%. The level of implementation of local DRLs is far from completed in Norway even though establishment of local DRLs became mandatory in 2004. A recalculation of the estimated CED from 2002, based on the mean patient doses observed in this survey, result in reduction of the CED of

17%. Expanding the concept of local DRLs to even more examination types will result in more accurate estimates of the CED from medical X-ray examinations when combined with updated numbers of examination frequencies. Increased focus on the role of local DRLs as an efficient tool to identify unusually high dose levels and as a first step in the optimization process of radiological examination protocols will probably reduce the national DRLs even further and hopefully also be able to slow down the rapid increase in the contribution to CED from medical examinations.

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