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18th South-East Asia Congress of Medical Physics (SEACOMP)
120th Scientific Meeting of Japan Society of Medical Physics (JSMP)
12th Annual Meeting of Thai Medical Physicist Society (TMPS)

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Facility reference level for common x-ray procedures: A preliminary study

DM Satharasinghe[1,2#], J Jeyasugiththan[1], AS Pallewatte[3] and WMNMB Wanninayake[2]

1 Department of Nuclear Science, Faculty of Science, University of Colombo, Sri Lanka.
2 Horizon Campus, Malabe, Sri Lanka.
3 Department of Radiology, National Hospital of Sri Lanka, Colombo, Sri Lanka.

Abstract

Ionizing radiation is an essential tool in medical diagnosis and it brings great benefit to the patient. However, the associated risks due to the radiation is unavoidable. Therefore, close monitoring of radiation exposure should be performed in order to control the potential harm. As an advisory measure to improve optimization of patient's radiation protection, Diagnostic Reference Levels (DRLs) was introduced by the International Commission on Radiation Protection (ICRP). The present study aims on the evaluation of the doses and its variation for selected x-ray procedures used by a single institution in Sri Lanka to determine a possible institutional DRL. The study included dose data and exposure parameters from 218 chest-Postero Anterior (PA), 33 abdomen-Antero Posterior (AP), 85 lumbar spine AP and 88 lumbar spine-Lateral (LAT) projections of patients (age between 19-78 years). The 3[rd] quartile dose values for above projections were 16, 256, 155, 455 $\mu Gy.m^2$ respectively. Further, the above dose values were compared with international DRLs and we found that the lumbar spine lateral projection and abdomen AP are with higher dose levels. This preliminary study provides information on the selected study setting only however, can be used as a reference for quality improvement programs by others.

Keywords: institutional diagnostic reference level, IDRL, Diagnostic reference level, DRL, ionizing radiation, x-ray

1. INTRODUCTION

The optimization of radiation protection in diagnostic radiology requires the use of appropriate examination-specific protocols tailored well with the patient age, size or body mass, region of imaging and clinical indication. This will ensure that the received doses are kept as low as reasonably achievable (ALARA) [1]. Accordingly, major national and international surveys had conducted on medical radiation exposures as early as in 1950 [2-3]. The aforementioned surveys that conducted in UK and USA mainly focussed only on diagnostic x-ray examinations. However, due to the varying definition used by different authors, comparison of values between publications were impossible. Therefore, the term "Diagnostic Reference Level" was introduced by the International commission on Radiation protection (ICRP) in 1996 [4]. This concept was subsequently developed further and guidance document for establishing DRLs were introduced in 2001 and 2017 [5-6]. According to the ICRP, DRL is considered as an advisory measure to improve optimization of patient protection by identifying high patient dose levels which might not be justified on the basis of image quality requirements [6]. This is applicable for all patients groups irrespective of age, gender or any other category. The main objective of DRL is to avoid radiation overdose to the patient that doesn't account for clinical requirement. However, the DRL is not intended to provide dose constrains to individual patients or studies to demarcate the good and bad practices [6].

During the present study, the variation of doses among most common x-ray procedures in a radiology facility were evaluated. The obtained results were compared with the international published DRLs to identify the procedures which required optimization. Finally the necessary recommendations were given. This is the first preliminary study conducted in Sri Lanka. Therefore, the results from present study would escalate the concern on use of appropriate exposures during x-ray procedures and to optimize the radiation dose received by the patient.

2. MATERIALS AND METHODS

This study was conducted in a radiology department of a well-established private hospital equipped with a digital flat panel system made of caesium iodide and amorphous silicon. The dimension of the fixed detector is 42.5 X 42.6 cm with pixel matrix of 2880 X 2880 X 148 µm. The dimension of the wireless detector is 35.3 X 42.4 cm with pixel matrix of 3072 X 2560 X 139 µm.

The permission was granted by the Head of the relevant department to conduct the study and ethical approval was waived since the patient identification data is not required. This respective department provides services to nearly 3000 patients per month covering range of plain radiographic studies.

The exposure parameters were recorded retrospectively. This includes 218 chest Posteroanterior (PA), 33 abdomens Anteroposterior (AP), 85 lumbar spine AP and 88 lumbar spine Lateral (LAT) projections of patients aged 19-78 years. The Doses were extracted from the Digital Image Communication in Medicine (DICOM) header in the form of Dose Area Product (DAP) measured in $\mu Gy.m^2$. This value is automatically appearing on the viewing monitor immediately following the exposure. For majority of exposures, Automatic Exposure Control (AEC) were utilized. During the AEC mode the mAs is automatically decided by the machine depending on the selected combination of the dose and the kVp which were set by the user. However, manual exposures were employed when imaging over or underbuilt patients to ensure an adequate quality image. Except for chest radiography other projections were done on table buckey with using a portable Wi-Fi flat panel x-ray detector. The chest PA projections were performed in the fixed detector wall

Table 1: Descriptive statistics of the technical parameters (tube current (mAs) and tube voltage (kVp)) and dose data (DAP μGy.m2) in the study sample. Mean value and standard deviation (range in parenthesis) are given.

Region	Projection	Sample size (n)	Age (years)	kVp	mAs	DAP μGy.m^2	3rd quartile of the DAP-μGy.m^2
Chest	PA	218	38.2 ± 13.7 (19-78)	124.9 ± 0.2 (124.3- 125.6)	2.8 ± 0.9 (1.6-6.6)	13.7 ±5.6 (3.6-37.8)	16
Abdomen	AP	33	41.8 ± 14.3 (20-68)	75.8 ± 5.4 (65.9-81.3)	38.9 ± 40.3 (6.8-211.1)	192.4±165 (34.3-860.6)	256
Lumbar Spine	AP	85	41.5 ± 13.5 (19-66)	72.5±3.6 (61.5-80.8)	40.9±26.1 (6.5-157.9)	124 ±82.5 (17.6-490.5)	155
	LAT	88	42 ±13.3 (19-66)	75.7 ±6.4 (62.9-90.3)	81.2 ±61.6 (3.6-312.7)	336.3 ±241.8 (11.2-1265)	455

buckey. The system was commissioned a year ago and calibrations were done regularly by the vendor.

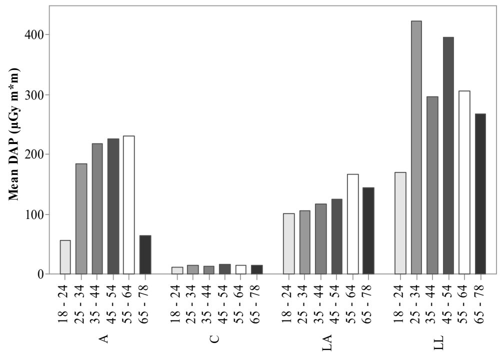


***Figure 1.** Histogram showing the mean DAP (μGy.m^2) values as a function of age categories for four different x-ray projections. **A**-Abdomen AP, **C** – Chest PA, **LA**-Lumbar Spine AP, **LL**-Lumbar Spine Lateral.*

Therefore, the displayed doses were considered accurate and reliable. The mean and third quartile value of the dose data and exposure parameters were calculated for each projection. Statistical analysis was done using Minitab® 17.1.0 statistical software.

3. RESULTS

The dose data with exposure parameter of 424 patients aged between 19 and 78 years (60.8% male) belongs to four different anatomical projections (chest, abdomen and lumbar spine AP and LAT) were evaluated. The mean, third quartile value and the range of the dose distribution were calculated. The obtained DAP values (μGy.m^2), kVp and mAs for each of the above projections are summarized in table 1.

***Table 2.** Comparison of 3rd quartile values of the present study with the international DRLs.*

Anatomy	Projection	DRL (μGy.m^2) Present study	UK [7]	Austria [8]	Germany [9]
Chest	PA	16	15	15	15
Abdomen	AP	256	250	210	230
Lumbar Spine	AP	155	150	200	200
	LAT	455	250	320	350

3.1 International comparison of DRLs

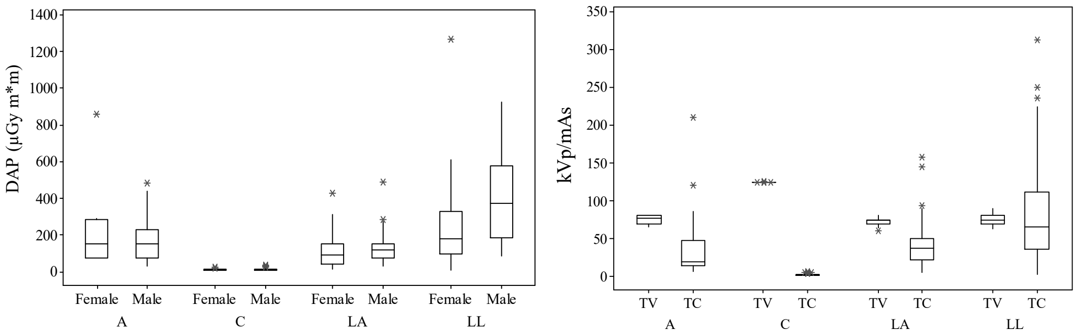
The obtained 3rd quartile dose values were compared with the established DRLs of England, Austria and Germany (see table 2). These countries had followed the similar concept and established their own DRL through nationwide patient's dose surveys. The DRLs are defined for an average adult and it differs from country to country [7-9]. The average adult is considered as a person with 70 kg [6]. But, the dose values in the present study are obtained for range of adult patients (19-78 years) without considering weight. This is a one limitation of the present study.

4. DISCUSSION

The 3rd quartile dose values for chest PA and lumbar spine AP are closely agreed with the international DRLs. The abdomen AP projection shows nearly a similar trend when compared to UK, but greater than the Austria (21%) and Germany (2.4%). Moreover, the 3rd quartile dose value for lumbar spine LAT projection is not comparable with those three countries. There is a large difference against UK study (82%).

Abnormally higher doses for the abdomen AP and lumber spin LAT projections may be due to several factors such as utilizing of inappropriately high radiographic technical parameters, patient positioning errors, calibration discrepancies of the equipment and many more. The DR system is more likely to result in overexposures due to its high exposure latitude compared to the conventional x-ray [10]. Consequently, it requires several times higher exposures until the signal saturation occurs and result in noticeable image quality degradation [10]. Regrettably, the patient in this situation received unnecessary radiation exposure, often without the knowledge of the technologist who involved in the image acquisition. Therefore, it is essential to evaluate the technical and the practice parameters of the above projection in order to identify the causes for the high exposure.

The figure 1 illustrates the mean DAP values for different x-ray projections and for different age groups. These dose values are demonstrated without biasing to the gender and it is observed that the mean dose for chest



(a) (b)

Figure 2 *Box-whisker plot of (a) gender wise variation of DAP per projection (b) kVp and mAs per projection. Abdomen AP (n=33), Chest PA (n=218), Lumbar spine AP (n=85) and Lumbar spine LAT (n=88). The 25th and 75th percentile marks the box and whiskers extend to the range outliers. The median is marked in the box. The asterisks (*) represent extreme values.* ***TV****- Tube Voltage,* ***TC****- Tube current,* ***A****-Abdomen AP,* ***C*** *– Chest PA,* ***LA****-Lumbar Spine AP,* ***LL****-Lumbar Spine Lateral.*

region is uniformly distributed among all age ranges. Patients aged, 18-24 years had exposed to the lowest dose of radiation during all procedures. However, there is no significant between age ranges and dose for all projections ($p < 0.05$).

Additionally, the influence of gender on delivered dose were also evaluated. Figure 2(a) demonstrates the resultant relationship between DAP and gender. The median dose delivered during abdomen AP, lumbar spine AP and chest PA were almost constant for both males and females. But male patients were receiving higher doses during lumbar spine lateral projections.

The median tube voltage is almost constant for all projections except for chest PA (figure 2(b)). For the chest PA projection, it is clearly seen that the highest tube voltage and lowest tube currents were used. This is due to the fact that chest region contain both high and low attenuation structures such as denser mediastinum and less dense lung tissue [10]. This will make a greater variation in subject contrast. Therefore, the utilization of high tube voltage with low tube current is recommended to visualize the lower lying lung field [11].

However, tube current utilized for the lumbar spine lateral projection is high and widely distributed. The higher tube current increases the production of electrons (or the quantity of radiation) [12]. This enables more photons to reach the x-ray detector and creates a greater signal intensity, i.e. a high quality image. Moreover, the median of the tube current used for the abdomen AP is more towards the 1st quartile. So, higher tube currents are used for abdomen AP and it may be a reason for the abnormally higher dose. A recent study carried out by Hawal and Hariwan (2017) confirmed that users always tend to set the tube lower voltages in the DR system. Therefore it will result in high tube current (i.e. High patient doses) [13]. Furthermore a phantom study showed that the entrance dose (ED) of 0.002 mSv is adequate to visualize the anatomical structures of the lumbar spine LAT projection [14]. In addition, they emphasize that exposure of 95 kVp and 4.5 mAs can reduce the ED by 63%. Therefore, utilization of high tube current should be justified based on the image quality requirement since tube current directly influence the dose delivered during an imaging procedure [15].

Finally, the radiologic technologists of the relevant institution were informed about these findings to emphasize the immediate requirement of a dose optimization protocol to avoid unnecessary radiation dose given to the patient. Also, it is very essential to evaluate the image quality of the projections which have higher dose levels so that an accurate diagnosis could be obtained with considerable dose saving.

This study will be extended in future and the post optimized protocols will be evaluated to quantify the achievement of the dose reduction. Therefore, we are recommending not only the dose reference levels for the aforementioned institution but also emphasize the requirement of regular dose and image quality monitoring. Furthermore, the 3rd quartile values of the dose distribution for chest PA, abdomen AP, LAT and lumbar spine AP can be used as the facility reference levels. The suggested reference values can be used to identify the unnecessary over exposures until the establishment of the DRL values matches for Sri Lankan context.

5. CONCLUSION

This is considered as a preliminary study to initiate a dose evaluation programmes in Sri Lanka. In the present study, the projections such as chest PA and lumbar spine AP were below or comparable with the international DRLs. Therefore, the 3rd quartile value of the dose distribution for the above projections are suggested as the facility reference levels which are 16 and 155 $\mu Gy.m^2$ respectively. The lumbar spine LAT and abdomen AP shows abnormally higher doses (3rd quartile values 455 and 256 $\mu Gy.m^2$ respectively) than that of the international reference levels. Therefore, optimization actions should be implemented for the above projection and should be followed by a re-evaluation survey. This preliminary study provides information on a selected radiology facility only, however this result can be used as a reference for quality improvement programs. In the future, in-depth study is essential to cover all the procedures which involves ionizing radiation for the medical diagnosis purposes.

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