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ESTABLISHMENT OF INSTITUTIONAL REFERENCE LEVEL OF RADIATION DOSE FOR RADIOTHERAPY COMPUTED TOMOGRAPHY SIMULATION PROCEDURES

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ABSTRACT

For the last two decades, diagnostic reference level (DRL) in medical imaging involving ionising radiation has become an essential tool for the optimisation of radiation exposure to the patients. A computed tomography (CT) simulator plays an important role in conformal radiotherapy to provide the volumetric information of the patient anatomy for the accurate delineation of the tumour and the critical structures. Optimization of radiation dose to patients during CT simulation procedures has not been a major concern in most countries; however, it cannot be ignored since the cancer patients may have a long life expectancy after their treatment. In addition, the As Low As Reasonably Achievable (ALARA) principle should be considered whenever ionising radiation is used. Therefore, this study aims to develop an institutional reference level of radiation dose for CT simulation procedures. Data from a total of 350 CT simulation procedures were accumulated from October 2022 to November 2022 at Apeksha Hospital-Maharagama, Sri Lanka. As per the ICRP recommendations, mostly performed CT simulations of anatomical regions were considered in this study, CT dose index (CTDI) volume and dose length product (DLP) were used as the DRL quantities, and the median values of the DRL quantities were calculated to define the DRL values. The established DRL values of the CTDI volume and DLP are 7.4 mGy, 394 mGy.cm for the abdomen region, 15.5 mGy, 454.5 mGy.cm for the chest region, 58.2 mGy, 2632 mGy.cm for the head region, and 9.3 mGy, 339 mGy.cm for the pelvis region, respectively. The developed DRLs for the thoracic region were higher compared to the other countries' values, but the developed DRLs for all other anatomical regions are lower. This study highlights the importance of optimizing radiation dose to patients. Further, we recommend developing national DRLs for mostly performed CT simulation procedures in Sri Lanka.

KEYWORDS: *Computed tomography simulation, Diagnostic reference level, Radiation protection, Dose optimization, Dose length product*

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1. INTRODUCTION

A computed tomography (CT) simulator is specially configured to acquire 3-dimensional images for radiotherapy treatment planning. It allows precise delineation of the tumour and the surrounding critical structures. There might be multiple CT examinations from diagnosis to treatment for a cancer patient (Goske M J, 2014). Higher resolution of CT images is required for the advanced radiotherapy techniques. With the advent of multi-detector CT (MDCT), there is a higher demand for CT scans annually (Rao S. et al., 2023). Due **to the higher demand for CT scans in diagnostic radi**ology and radiotherapy, **there is growing concern about radiation exposure to patients not only in CT scans but also for all imaging** procedures involving ionising radiation. Therefore, optimisation of radiation dose in medical imaging is vital (Ramanathan V et al., 2023). In this scenario, a diagnostic reference level (DRL) was introduced by the International Commission on Radiological Protection (ICRP) in 1996 (ICRP, 1996).

DRLs are not defined for individual patient applications and should not be used as dose limits. Rather, the DRL represents an essential tool in the optimisation process, especially since dose limit values are not relevant in the context of the medical exposure of patients. When conducting studies to determine dose information for various procedures, it is important to identify too low and too high radiation doses, as both can have consequences for the patient (ICRP, 1996). The ICRP recommended DRL quantities for CT imaging are Computed Tomography Dose Index (CTDI) and Dose Length Product (DLP), which can be collected directly from CT machine parameters.

The DRL values for the CT simulation procedures have been developed in some countries. Recent publications show the interest in developing DRLs for CT simulation procedures to support it [(Zalokar et al., 2020),(Rao et al., 2022), (Bozanic et al., 2022)]. Therefore, this study aims to develop institutional DRLs for CT simulator at the National Cancer Institute (NCI), Maharagama, Sri Lanka.

2. METHODOLOGY

This observational analytical study was conducted at Apeksha Hospital- Maharagama, Sri Lanka. Data were collected from Toshiba Squillion large bore CT scanner in the CT simulator Unit during the period spanning two months, from October 2022 to November 2022.

During the data collection period, 350 patients aged 18 to 90 years were randomly selected from the stored data. The patients under 18 years of age were excluded due to their significantly lower CT radiation dose and variable sizes. According to the recommendation of the ICRP, mostly performed CT simulation procedures, such as head, chest, abdomen, and pelvis regions, were selected in this study. All the scans were non-contrast.

The collected data were in the form of dose reports stored as digital imaging and communications in medicine (DICOM) images. The study could not compare radiation dose based on patient weight groups since patients' weights were not available in the stored data. However, a relatively large amount of data was accumulated according to the ICRP's suggestions. The study ensured that at least 30 CT simulation procedures were collected for each selected region.

The ICRP recommended DRL quantities for CT scan of CTDI volume and DLP were gathered from the stored data. The collected data were recorded separately based on the anatomical regions. In order to establish the DRL values for CTDI volume and DRL, the 25^{th}, 50^{th} and 75^{th} percentiles were calculated for each anatomical region separately. According to the ICRP recommendations, the value of 50^{th} percentile (median) values were considered as the newly developed DRLs for the selected CT simulator Unit at Apeksha Hospital. The data analysis was performed using the Statistical Package for Social Sciences (SPSS) software.

3. RESULTS AND DISCUSSION

The data set included 350 samples in the valid age group with a range from 19 to 87 years old. The distribution of age is shown in Figure 1.

The mean age was reported as 58.96. The collected data consists of 176 (50.3%) female patients and 174 (49.7%) male patients. This represents an almost equal gender distribution.

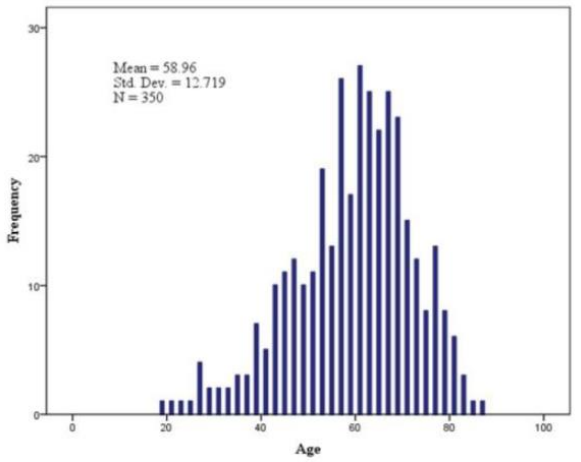

Figure 1: Distribution of patient age group included in CT simulation procedures

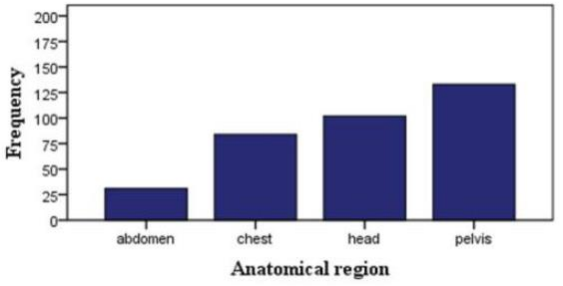

Figure 2: The distribution of mostly performed anatomical regions.

This study considered four commonly imaged anatomical regions: the abdomen, chest, head, and pelvis. The majority of scans were of the pelvis, accounting for 38% of all scans. This suggests that CT scans of the pelvis were the most commonly performed scans in the population. The head was the next most common anatomical region imaged, accounting for 29.1% of all scans (Figure 2).

The 25th, 50th, and 75th percentiles of CTDI volume and DLP values for each anatomical region were shown in table 1. The 50th percentile was considered for the newly established DRL values since this study considered only one institute. The established DRL values were 7.4 mGy and 394 mGy·cm for the abdomen region, 15.5 mGy and 454.5 mGy·cm for the chest region. For the head region 58.2 mGy and 2632 mGy·cm and for the pelvis region 9.3 mGy and 339 mGy·cm. These were the DRL quantities of CTDI volume and DLP, respectively.

Table 1: The descriptive statistics for CTDI volume and DLP. Per. **indicates** percentile.

		CTDI volume (mGy)			DLP (mGy.cm)		
		25th Per.	50th Per.	75th Per.	25th Per.	50th Per.	75th Per.
Anatomic	Abdomen	5.6	7.4	13	256	394	548
	Chest	11.1	15.5	22.3	312.5	454.5	649
	Head	58.2	58.2	63.5	2269	2632	3161
	Pelvis	6.8	9.3	15.5	241	339	555

The comparison of developed DRL values of CTDI volume of NCI-Sri Lanka with other countries (Slovenia -Zalokar et al., 2020, India- Rao et al., 2022, and Croatia- Bozanic et al., 2022) reveals that the abdomen and the pelvis regions in NCI-Sri Lanka are lower than those in Slovenia and Croatia. However, the DRL value for the chest region in NCI-Sri Lanka is higher than that in Slovenia and Croatia. For the head region, the value in NCI-Sri Lanka is lower than that in Slovenia but higher than that in Kasturba Hospital, Manipal, Karnataka, India, and Croatia (Figure 3).

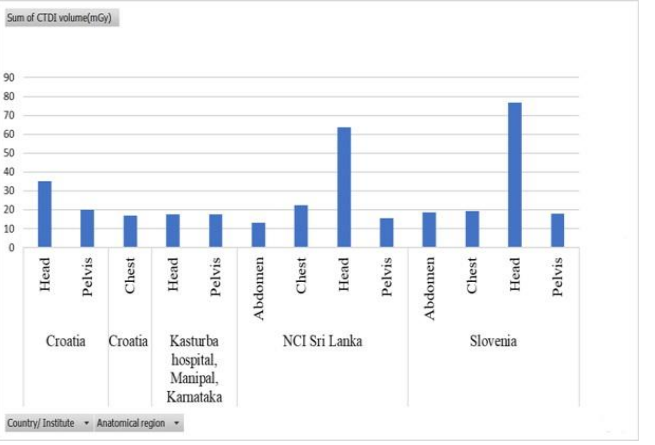

Figure 3: The comparison of the DRL values of CTDI volume with other countries [Slovenia (Zalokar et al., 2020), India (Rao et al., 2022), and Croatia (Bozanic et al., 2022)].

The DRL values of DLP for the abdomen and pelvis regions in NCI-Sri Lanka are lower than those established DRLs in Slovenia and Croatia. The DRL value for the chest region in NCI-Sri Lanka is lower than that in Slovenia and Croatia. For the head region, the DRL value in NCI-Sri Lanka is higher than that in Slovenia, Kasturba Hospital (Manipal, Karnataka), and Croatia (Figure 4).

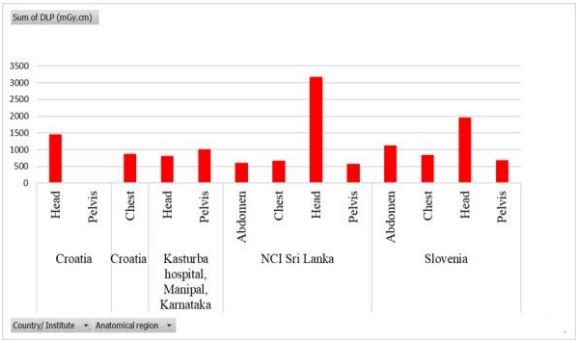

Figure 4: The comparison of the DRL values of DLP with other countries [Slovenia (Zalokar et al., 2020), India (Rao et al., 2022) and Croatia (Bozanic et al., 2022)].

The established diagnostic reference levels (DRLs) for the non-contrast CT simulation procedures at the NCI, Sri Lanka and the national diagnostic reference levels (NDRLs) for the non-contrast computed tomography procedures in Sri Lanka show some differences in terms of CTDI volume and DLP values. For the abdomen region, the NDRLs for CTDI volume is lower than the established DRLs at the NCI, Sri Lanka but the DLP value is higher in NDRL-Sri Lanka. The NDRLs for the chest region have lower CTDI volume and DLP values compared to the NCI-Sri Lanka's established DRLs. However, the NDRLs for the head region have a higher CTDI volume value but a lower DLP value than the established DRLs at the NCI Sri Lanka. For the pelvis region, the NDRLs have a higher CTDI volume and higher DLP value than the established DRLs at the NCI Sri Lanka (Figure 5 and Figure 6).

The higher DRL values observed in this study, particularly when compared to national diagnostic reference levels (NDRLs), can be explained by the unique requirements of radiotherapy CT simulations. Unlike diagnostic CT, radiotherapy planning often necessitates extended scan ranges to include regional lymph nodes based on tumour spread, resulting in increased scan length and dose. Additionally, at NCI Sri Lanka, a single head protocol is used for both brain and head-and-neck cases, which may contribute to elevated dose values in the head region. These protocol differences, combined with patient variability, highlight the need for dedicated DRLs tailored specifically to radiotherapy simulations rather than relying on diagnostic standards.

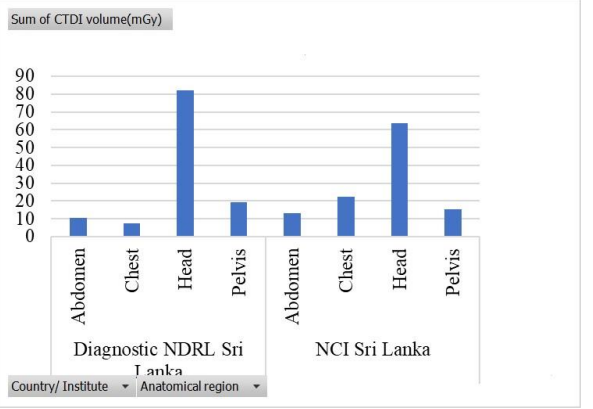

Figure 5: The comparison of current established DRL values of CTDI volume with National DRL values of diagnostic computed tomography in Sri Lanka (Amalraj et al., 2022).

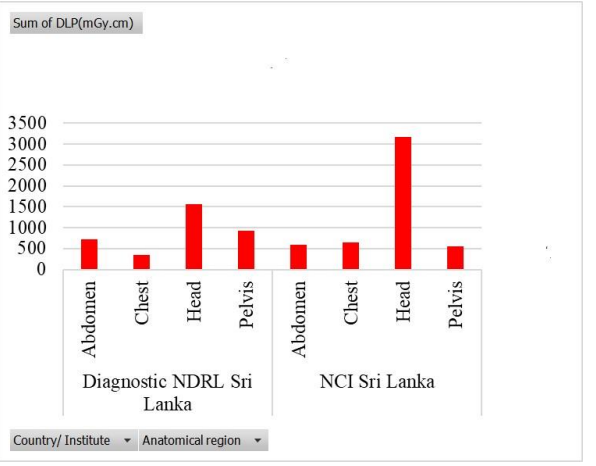

Figure 6: The comparison of current established DRL values of DLP with National DRL values of diagnostic computed tomography in Sri Lanka (Amalraj et al., 2022).

Moreover, differences in the mean age and body weight of patients between the current study and those used in the national DRL survey may have contributed to the observed dose variations. Although patient weight data

were unavailable, this factor should be considered when interpreting dose comparisons.

Further evaluation is necessary to determine the appropriateness of these lower CTDI volume and DLP values in maintaining patient safety and minimizing radiation exposure during radiotherapy CT simulation procedures.

4. CONCLUSION

The DRL values of CTDI volume and DLP quantities have been successfully developed for mostly performing CT simulation procedures at the National Cancer Institute in Maharagama, Sri Lanka.

The study's results can be used by the National Cancer Institute, Maharagama, and other healthcare facilities in Sri Lanka to evaluate the radiation doses used in their CT simulation procedures. Further, this study recommends **developing** national DRL for CT simulation procedures in Sri Lanka.

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