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Establishment of facility diagnostic reference levels for computerized tomography of head, chest and abdomen investigations

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► ***Short report***

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ABSTRACT

Background: The Computed Tomography is a major contributor to patient radiation exposure in diagnostic radiology. This study aimed to establish facility-specific CT Diagnostic Reference Levels for head, chest and abdomen examinations to optimize radiation doses while maintaining diagnostic image quality. The diagnostic reference levels serve as benchmarks to enhance radiation protection by adjusting scanning parameters. The establishment of facility diagnostic reference levels provide a base line for future dose reduction strategies. ***Materials and Methods:*** Adult patient data for head, chest, and abdomen scans were collected from the facility's 128-slice CT scanner. The facility volumetric computed dose index and dose-length product data was recorded on Microsoft excel sheet. The first, second and third quartile values were determined, and the facility diagnostic reference levels were established as the third quartile of the median volume CT dose index and dose-length product values for head, chest and abdomen examination. ***Results:*** The determined median volumetric computed dose index for head, chest and abdomen was 41.9 mGy (IQR: 41.9-46.35 mGy), 29.5 mGy (IQR: 28.3-29.5 mGy) and 29.5 mGy (IQR: 29.5-42.98 mGy) respectively. The corresponding median dose-length product values were 810mGy·cm (IQR: 768.5-931.6 mGy·cm) for head, 1220 mGy·cm (IQR: 1031.45-1312.9 mGy·cm) for chest, and 1694.5 mGy·cm (IQR: 1529.68–2247 mGy·cm) for abdomen. ***Conclusion:*** The study findings support the development of local and national benchmarking databases for CT radiation doses. The evaluated F facility diagnostic reference levels provide a base line for future dose reduction strategies used for standardization and radiation doses optimization in CT imaging.

INTRODUCTION

The use of ionizing radiation is increasing with the introduction of advance diagnostic modalities since the discovery of X-rays in late nineteenth century. The Computerized Tomography (CT) has become a power full diagnostic tool in medical imaging. However, radiation doses to the patient in CT investigations are substantially higher than that of conventional radiography [1-3]. The high radiation doses associated with CT necessitates to avoid and reduce its unnecessary use and protect the patients by adjusting CT scan parameters without compromising image quality in justified medical exposure applications. The International Commission on Radiological Protection (ICRP) recommended a radiation protection system for medical usage of ionizing radiations - Justification, Optimization and Dose constraint [4]. For a justified practice, optimization is the next step that can minimize radiation exposure to the patient. The Diagnostic Reference levels (DRLs) concept was introduced in 1990 and its implementation was recommended in the ICRP-60 and ICRP-73 to optimize medical imaging practices [5, 6]. These recommendations prompted various professional bodies and regulatory authorities across the world to set and recommend DRLs for medical imaging practices [7-9]. The easily and reproducibly measured dosimetry quantities recommended for the establishment of DRLs in CT assisted investigations are volumetric CT Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP) [10, 11]. Subsequently many clinical radiological facilities at local and regional levels determined and reported CT DRLs [12-16].

The primary aims of this study were to establish Facility Diagnostic Reference Levels (FDRLs) for adult head, chest and abdominal CT examinations as a reference point to evaluate radiation dose indices and to compare these FDRLs with those established and reported in the literature. The data generated in this study provides a base line for future dose reduction strategies for standardization and optimization and will contribute to local and national DRLs data base.

MATERIALS AND METHODS

The data of adult patient's head, chest and abdomen CT scans performed at facility radiology

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department on 128 slice CT system (Toshiba Aquilion CX, NCB1272405) was used in this study to evaluate Facility Diagnostic Reference Levels (FDRLs) for these examinations. The $CTDI_{vol}$ and DLP are radiation dose output parameters directly taken from patient protocol and were recorded in structured format for the period from 1st September 2023 to 30th April 2024. The data values were confirmed where required from local Picture Archive Communication System (PACS). The data were saved in a Microsoft Excel spreadsheet and categorized for the examination parameters and anthropometric parameters. Effective Dose (ED) was calculated by multiplying conversion coefficient of each body region with corresponding DLP values (16, 17).

Statistical analysis

The $CTDI_{vol}$, DLP and ED data of adult patient's head, chest and abdomen CT scans was tabulated and organized into different Microsoft Excel sheets. The first quartile, mean, second quartile and third quartile values were determined to understand dataset central tendency and its variability to find outliers. The facility DRLs were determined as third quartile for head, chest and abdomen CT investigations (18). The determined FDRLs were compared with published international reports.

RESULTS

Over all 3333 CT scans were performed during the period from 1st September 2023 to 30th April 2024 including 503 head (15%), 204 chests (6%) and 612 abdominal scans (18%). The mean ±SD age of the patients who underwent head, chest and abdominal CT was 49.18 ± 19.4, 51.701 ± 7.5 and 47.6 ± 17.6 respectively.

The quartiles help to understand dataset central tendency and its variability to find outliers. The first quartile shows the value below which 25% of the distribution falls, second quartile indicates value below which 50% of data falls and third quartile shows the value below which 75% of data falls.

The first and second quartile value for head $CTDI_{vol}$ is 41.9mGy showing low variability and tight clustering of the data around this value. The third quartile value determined is 47.55mGy. The median is 41.9 mGy, with a relatively narrow interquartile range (IQR = Q3 - Q1 = 47.55 - 41.9 = 5.65), indicating consistent doses.

For chest and abdomen first quartile value is 28.3mGy, second and third quartile is 29.5mGy, showing minimal variability in the distribution data and reflecting good standardization within the facility. The CT head DLP values of the first, second and third quartile show relatively tight distribution around the median value of 810 mGy.cm. It shows that most of the procedures were performed on low dose protocols. The CT head ED values determined are 1.61 mSv, 1.7 mSv and 1.96 mSv for first, second and third quartile quartiles respectively. These values are relatively consistent and show narrow range. Inter quartile range difference (IQR) for first quartile and third quartile is of 0.35 mSv which is quite small, indicating very little variation in patient doses. Similarly, median value (1.7 mSv) is very close to both quartile values, reflecting consistent CT imaging protocols and dose optimization being practiced in the facility.

The first, second and third quartile values for CT chest are 14.44mSv, 17.08mSv and 18.38 mSv respectively. The interquartile range is 3.94 and the whisker is 8.53, 24.29, indicating moderate variability in the data distribution. The CT head ED values determined are 22.5 mSv, 25.42 mSv and 33.71 mSv for first, second and third quartile respectively. The interquartile range is 11.21 (18.38 - 14.44 =11.21). The value is too high and shows high variability in abdominal dose distribution.

DISCUSSIONS

The establishment of DRLs is considered valuable measure for the radiation doses optimization in diagnostic radiology investigations, specifically for CT investigation where doses incurred to the patients are high. The Pakistan national regulatory authority has recommended DRLs for adult head, lumber spine and abdomen CT investigations (8) and little published data for the country is available in the literature (7, 19, 20).

This study presents preliminary established FDRL for head, chest and abdomen for specific CT scanner used in our institution. The study distribution that falls in the top first percentile of distribution needs to be reviewed as the corresponding image quality becomes non-diagnostic. Similarly, the study distribution that fall in second percentile show that half of the image are produced at lower doses and half are produced at higher doses. The FDRLs for CT head, neck and abdomen were determined (figures 1-3) and set as the 75th percentile of the study dose distribution as a baseline for future dose parameters audits and reviews (21). The procedures distribution falling in third percentile need to be subjected to dose reduction strategies without compromising diagnostic outcome. The values above 75th percentile need CT protocols and dose parameters review.

The reported FDRLs for head $CTDI_{vol}$ and DLP are in agreement with the National, European, USA, and Australian DRLs. The chest and abdomen FDRLs are higher than the UK, European, USA and Australian DRLs for these examinations (8, 9, 22). The $CTDI_{vol}$ values for abdomen DRL are also higher than the national DRL (7). The DRLs for chest and abdomen DLP are not recommended by the Pakistan National

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Regulatory Authority to date. These investigations require optimization by reviewing the equipment quality control results compliance with recommended standards, procedures, protocols and scanning parameters. After identifying the reason for higher values optimization actions can be initiated. The discrepancies observed in DRLs values comparisons can be due to variations in imaging equipment, clinical protocols, patient sample sizes, and demographic characteristics [22]. The re-evaluation of determined DRLs after periodic review of scan protocols and techniques will provide a better understanding of comparison with respective DRLs. The effective doses determined for the head CT are comparable with UK, ACR and Australian values but are relatively high for chest and abdomen investigations, necessitating optimization in these examinations table 1.

Table 1. Comparison of facility diagnostic reference levels VS national and international published values.

Investigation	RMI FDRLs			National DRLs (PNRA)			European DRLs			USA DRLs			Australian DRLs			UK DRLs		
	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	ED (mSv)	CTDIvol (mGy)	DLP* (mGy.cm)	ED* (mSv)	CTDIvol (mGy)	DLP (mGy.cm)	ED (mSv)	CTDIvol (mGy)	DLP (mGy.cm)	ED (mSv)	CTDIvol (mGy)	DLP (mGy.cm)	ED (mSv)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	ED (mSv)
Head	47.55	931.6	2.01	50	-	-	60	1000	1.9	62	1120	3	52	880	1.9	47	790	0.98
Chest	29.5	1302	18.23	-	-	-	10	400	6.6	17	610	13	10	390	5.7	8.5	290	4.1
Abdomen	29.5	1673.8	25.11	25	-	-	25	800	11.3	17	810	16	13	600	9.7	10	530	7.4

*not given

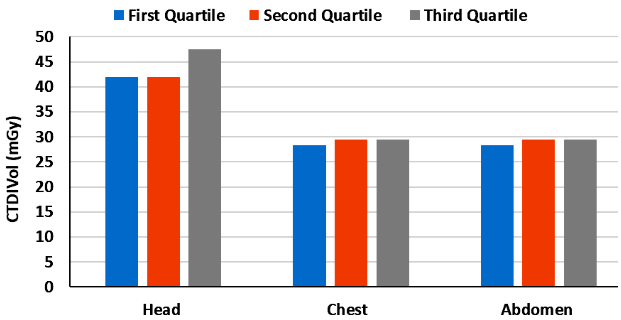

Figure 1. Bar Chart of CTDIvol DRLs for determined head, chest and abdomen.

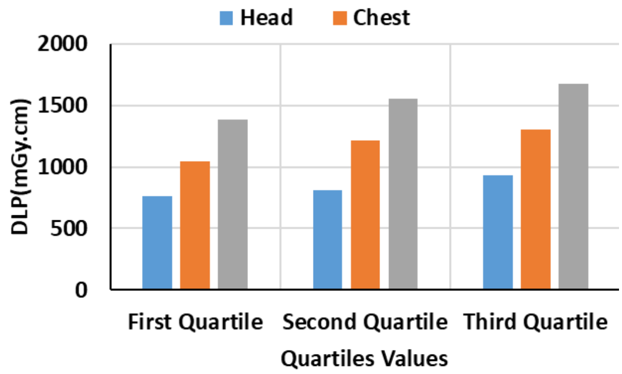

Figure 2. Bar Chart of DLP DRLs for determined head, chest and abdomen.

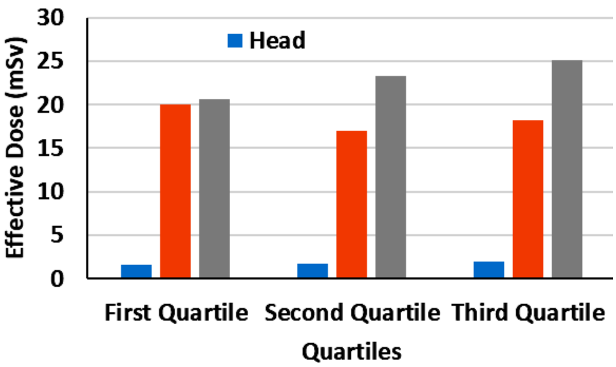

Figure 1. Bar Chart of CTDIvol DRLs for determined head, chest and abdomen.

CONCLUSION

The establishment of reported facility DRLs provides a base line to the department for future dose reduction strategies in CT imaging protocols. This study will also contribute in promoting local and national data base for benchmarking CT radiation doses. We expect with improved optimization and adjusting scanning parameters we will be able to observe dose reduction in future radiation dose audits in the facility.

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***Conflict of interest*:** There is no conflict of interest.

***Authors contribution*:** All authors contributed equally to conception and design of the work, active participation in methodology, critically phrasing of important clinical contents, evaluations of study parameters, drafting the work and revising it for publication. All authors discussed the results and contributed to the final version of the manuscript.

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