

Radiation Dose Optimization in Indian Computed Tomography: Current Diagnostic Reference Levels and Future Directions

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ABSTRACT

CT Scan is important for both diagnosing and monitoring medical conditions. However, the increased use of CT has raised concerns about patient radiation exposure to optimize the radiation dose while maintaining the best diagnostic image quality, Diagnostic Reference Levels (DRL) must be established to define any unusual increases in radiation dose. This study examines CT DRLs in India. Published articles were reviewed in this work in Indian context on the adult Diagnostic Reference Levels for specific anatomic regions to identify the cause and extent of deviations and to examine possible strategies to optimize Computed Tomography radiation dose. Variations in radiation dose within and among Computed Tomography centers are frequently reported, including scanning technology, study design, and the use of computed tomography parameters. There are only few studies published on DRLs in India. These types of studies are essential for developing national standards in different regions of the country and to provide a valuable and correct comparison with international DRLs.

Keywords: Computed Tomography, CT Dose Index, Diagnostic Reference Levels, Dose-Length Product.

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INTRODUCTION

Computed Tomography is also called computed axial tomography, CT scan, or CAT scan. It is an accepted imaging method to evaluate the whole body. The Images are acquired directly in the axial plane of varying tissue thickness. The advantage of these tomographic images compared to conventional X-rays is that they contained detail information about specific parts of the cross-section through computer imaging. Some pathology can be seen in the sagittal and coronal planes by reconstruction of the images by the computer. CT has undergone many changes, and now multi-detector CT scanners have been evolved which have better application in clinical field. The development of helical and multi detector row arrangements has improved CT applications (Prokop, 2003). CT scans use ionizing radiation that can travel

through the body and produce images of structures present inside the body. CT is associated with high radiation doses. As a result, cautious application of this imaging modality necessitates a strict commitment to radiation protection principles: justification, optimization, and minimization, ensuring that patient risk is not greater than the gained benefit from the technique (Tsapaki *et al.*, 2006; Vetter, 2008). The methods and wide range of exposure parameters used by modern CT scanners can greatly affect the radiation dosage that is administered to the patient. The development of Multi-Detector Computed Tomography (MDCT), which allows for more detailed anatomical information and diagnosis with greater accuracy, revolutionized diagnostic medicine. This is accomplished via multi-planar reformation, isotropic volume data collection, and images that are less than 1 mm thick. Many radiographic and fluoroscopic exams are now replaced by MDCT. Among all the diagnostic modalities, CT examinations provide the highest radiation dose. For example, the radiation dose of a routine volumetric single-section chest CT technique is more than a hundred times of the total radiation dose from frontal and lateral chest radiograph. Over the past three decades, there has been a noticeable increase in the number



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of CT exams performed (Varghese *et al.*, 2018). High-quality images should be captured during CT examinations that focus on specific clinical goals without giving an unnecessary dose to the patient. Therefore, ICRP suggested the idea of DRL and the priority is to optimize the patient's radiation dose.

This study reviewed established DRLs for CT examinations used in India. Our objectives were to (1) Analyze CT DRL in India (2) Identify factors that influence DRL variability, and (3) Explore strategies that can optimize CT radiation dose in the Indian health care context.

CT DOSE DESCRIPTORS

Dose Length Product (DLP)

A CT tube emits milli grays per centimeter as a Dose Length Product (DLP). DLP considers the radiation source's z-axis length (the patient's long axis) (Bushberg and Boone, 2011; Durand and Mahesh, 2012). It uses one phantom slice to monitor dosage. $DLP = (CTDI_{vol}) \times (\text{length of scan, cm})$ (Figure 1).

The unit to measure DLP is mGycm.

Computed Tomography Dose Index (CTDI)

CT imaging measures radiation dose using the Computed Tomography Dose Index (CTDI). CTDI is a standard metric of CT scanner radiation dose output that lets users compare CT scanners. We quantify CTDI in mGy. Initial measurements included CTDI across a 100-mm ionization chamber ($CTDI_{100}$) and weighted readings. Nowadays, helical scanners use $CTDI_{vol}$ instead of $CTDI_{100}$ and $CTDI_w$ (McNitt-Gray, 2002) (Figure 2).

Diagnostic Reference Level (DRL)

Optimizing with DRLs is feasible. diagnostic Reference levels are investigation levels used to optimize patient protection during diagnostic and interventional procedures. In medical imaging using ionizing radiation, it indicates whether a procedure's radiation dosage is too high or low for everyday regular conditions (Vaño *et al.*, 2017). In 1989, the UK proposed national reference dosages for some frequent radiographic examinations after a mid-1980s national survey found significant variability in hospital practices for similar procedures (Kerr, 1991). In 1990, the International Commission on Radiological Protection (ICRP) introduced diagnostic reference levels and developed them with publication 73 and 105 and ICRP supporting advice 2; Diagnostic reference level is "a form of investigation level, apply to an easily measured quantity, usually the absorbed dose in air, or tissue-equivalent material at the surface of a simple standard phantom or representative patient," according to the ICRP (Harding and Thomson, 1997). Diagnostic radiology national and regional reference values are usually the 75th percentile of sample average doses. Because facilities in different countries and regions may have different equipment and procedures, DRLs must be updated constantly with technology updates (Figure 3).

TECHNOLOGICAL ADVANCEMENTS IN CT DOSE OPTIMIZATION

The DRL serves as the standard for keeping radiation exposure in medical imaging as low as possible without compromising the ability to provide important diagnostic data (ALARA). In CT imaging, various optimization strategies and techniques have been developed and implemented to reduce patient radiation dose while maintaining diagnostic image quality. Here we present some common strategies and their approximate CT dose reduction.

Automatic Exposure Control (AEC)

The AEC modulates tube current based on patient anatomy and size to deliver radiation only where needed. Compared to fixed tube current scanning, this method reduces dosage by 25-50% (McCollough *et al.*, 2006) (Figure 4).

Tube voltage selection (kVp optimization)

Lowering tube voltage (kVp) reduces patient dose and maintains image quality. A 10 kVp reduction reduces dosage by 20-30% (Kalra *et al.*, 2004).

Iterative reconstruction Algorithms

Iterative reconstruction reduces noise and artifacts, allowing lower radiation doses. These algorithms minimize dosage by 30-60% over filtered back projection (Willemink *et al.*, 2013).

Pitch Adjustment

If the value of the pitch (feed revolutions per table) increases, it is possible to reduce the overlap of the received data, resulting in a dose reduction of 10-40%. However, in some cases, high pitch values can degrade image quality (McCollough *et al.*, 2006).

ARTIFICIAL INTELLIGENCE APPLICATIONS IN CT

CT is fast changing because to AI's ability to balance radiation dose reduction and image quality. AI has the potential to improve CT imaging, according to meta-analysis of five clinical validation trials with 929 participants between 2022 and 2024 (Zhang *et al.*, 2025). Recent studies show that AI-based interventions, particularly using deep learning algorithms like CNNs, enhance image quality across multiple anatomical regions with a mean difference of 0.70 (95% CI 0.43-0.96; $p < 0.001$), without affecting diagnostic accuracy.

AI-enhanced low-dose CT (LDCT) uses improved noise reduction and artifact correction to produce images comparable to standard-dose CT scans. This is especially useful in radiation-dose-minimizing applications like lung cancer screening and liver lesion identification, where diagnostic fidelity is crucial. Machine learning techniques offer patient-specific

dosage prediction based on scanner characteristics and demographics, allowing individualized scan protocol changes to maximize dose and picture quality.

AI-driven workflow optimization automates protocol selection, patient placement, and real-time dosage monitoring in CT operations beyond picture reconstruction. In resource-limited Indian healthcare institutes like KMC Manipal, AI-enabled workflows improve patient safety and departmental efficiency, but infrastructure and training issues remain (Maleki Varnosfaderani & Forouzanfar, 2024). . Low-dose image enhancement, tailored dosage prediction, and workflow automation are key AI uses in CT that increase patient safety and diagnostic outcomes. Future study should focus on standardization and clinical integration for varied healthcare environments like India.

Comparative Analysis: Indian DRLs and International Benchmarks (McCollough *et al.*, 2025).

Examination	India (South India) CTDIvol	India (South India) DLP	International (IAEA/EC/UK/USA) CTDIvol
Head	27-47	620-1041	47-60
Chest (Non-contrast)	10	445	9.5-15
Chest (Contrast)	-	-	10-15
Abdomen	12-16	482-550	10.9-14
Pelvic	-	-	400-650
Cervical Spine	-	-	17-28

Policy and Regulatory Framework

To use Computed Tomography (CT) safely and effectively while avoiding radiation exposure in healthcare, strong laws and

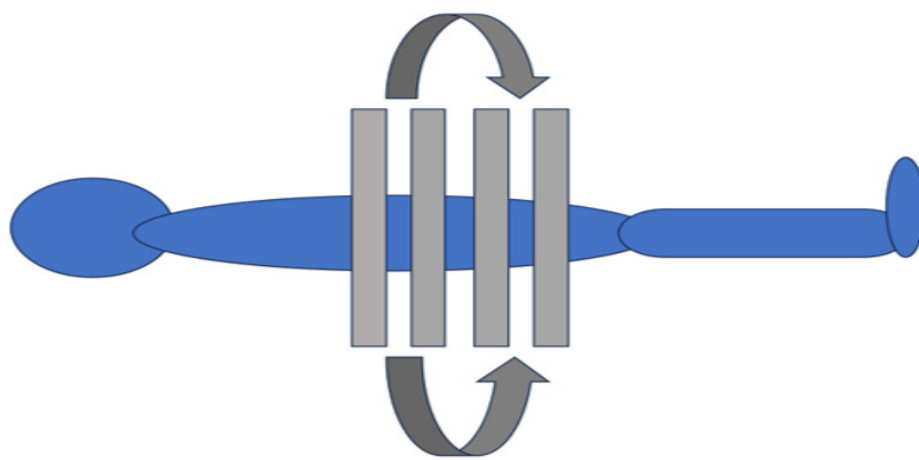
regulations are needed. Nationwide Radiation Protection Policies The Atomic Energy Regulatory Board (AERB) regulates dose limits, equipment certification, and licensing in India. Recent AERB National Diagnostic Reference Levels (DRL) guidelines emphasize dose optimization adapted to regional needs and align with ICRP and WHO standards, supporting global radiation safety goals Quality Control and Accreditation QA programs are becoming important for radiation dose monitoring and imaging standards. Hospital certification authorities like the National Accreditation Board for Hospitals and Healthcare Providers (NABH) require structured dose audits and equipment checks for radiation safety. QA measures improve diagnosis accuracy and patient safety Capability-building training.

Radiologists, technologists, and medical physicists must be trained to defend against radiation. National initiatives by AERB and organizations like the Indian Radiological and Imaging Association encourage dose optimization, DRL application, and future technologies like AI in CT dose control through workshops, certification, and CME. This continual training helps clinicians adapt to India's different clinical situations (Das *et al.*, 2025).

Ethical and Clinical Considerations

Computed tomography ethics require balancing radiation exposure and diagnostic quality. Clinicians must keep doses as low as reasonably feasible (ALARA) without compromising diagnostic accuracy to avoid radiation exposure and get clinically meaningful information. Informed consent and collaborative decision-making require patient information regarding radiation risks, procedure advantages, and alternatives.

Radiologists, medical physicists, technicians, and referring physicians must work together to improve scan protocols, monitor



$$\text{DLP} = \text{CTDI} \times \text{Scan Range}$$

Figure 1: DLP (Dose length product).

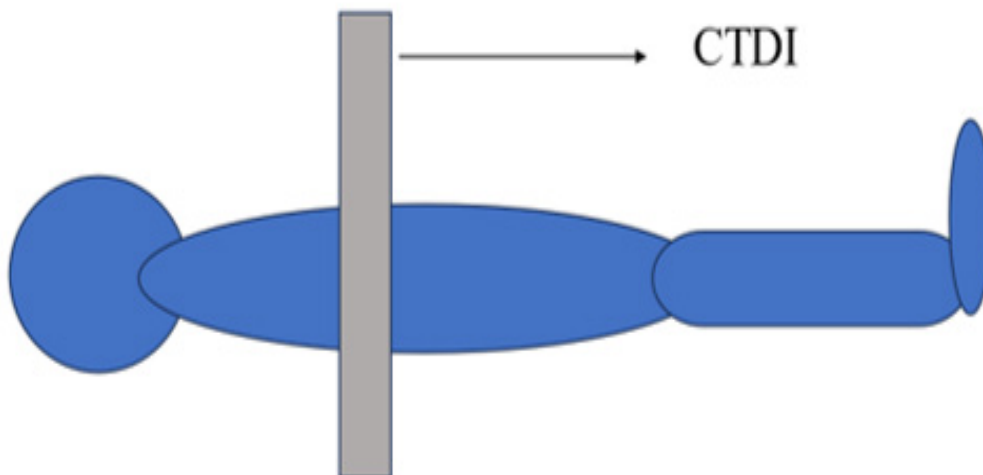
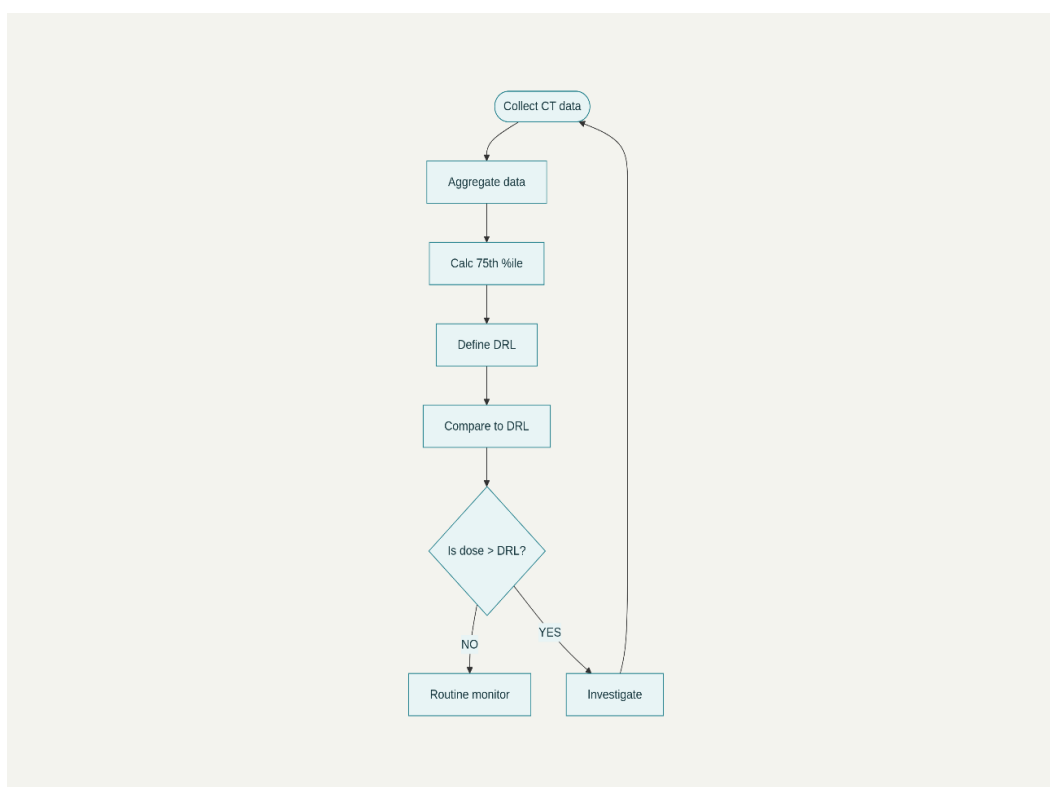


Figure 2: CTDI (Computed tomography dose index).



Flow Chart Showing Working of DRL.

Table 1: National Diagnostic Reference Levels (NDRL) for CT currently used in different states of India (CTDI=mGy, DLP=mGy/cm).

State	Descriptor	Head	Chest	Abdomen
South India	Computed Tomography Dose Index (CTDI _v)	47	10	12
	Dose length product (DLP)	1041	445	550
Pudhucherry, India	Computed Tomography Dose Index (CTDI _v)	32	12	16
	Dose Length Product (DLP)	925	456	482
Kerala, India	Computed Tomography Dose Index (CTDI _v)	27	5	9
	Dose Length Product (DLP)	620	164	319

dosages, and ensure patient safety. This partnership promotes diagnostic imaging safety and ethics (Brady *et al.*, 2024).

FUTURE PERSPECTIVES

Photon-counting CT reduces patient radiation exposure by improving spatial resolution and dosage efficiency over conventional CT detectors. Quantum computing is being studied to improve complex picture reconstruction and optimization to speed up and improve dose reduction. Big data analytics use large patient datasets to dynamically alter CT procedures for real-time dose monitoring and individualized radiation management (Das *et al.*, 2024). For safety and efficacy, clinical validation of these sophisticated technologies and India-specific models that represent regional imaging practices and patient demographics should be prioritized in future research.

DISCUSSION

Standardizing diagnostic reference levels for operations in different modalities is one technique to reduce radiation dose.

(Livingstone and Dinakaran, 2011) conducted the first Indian DRL study in 2011. Regional DRL is created in Tamil Nadu, South India. This study was part of the AERB-funded CT dose measuring effort on 127 Tamil Nadu CT scanners from 2006 to 2008. A 32-cm Polymethylmethacrylate (PMMA) body phantom measured CTDI, which was utilized to create DLP for different body areas. The regional DRLs for the thorax, abdomen, and pelvis were 557, 521, and 294 mGy/cm. All scanners were quality-checked before regional dose estimate. CT thorax,

abdomen, and pelvis mean effective doses were 8.04, 6.69, and 4.79 mSv, respectively, based on DLP values.

We included three articles in this review (Das *et al.*, 2024; (Livingstone and Dinakaran, 2011). CT National Reference Levels (NDRL) for Indian states are shown in Table 1. In different parts of India, DRLs vary greatly. Kerala has a CT head CTDI of 27mGy, while South India has 47mGy. Equipment, protocol, and local practices vary by location nationwide. This discrepancy emphasizes the necessity for a standard NDRL approach in India.

South India's study (Saravanakumar *et al.*, 2016; Saravanakumar *et al.*, 2015). included Tamil Nadu, Puducherry, Kerala, and Karnataka (110 CT scanners). All CT scanners in this investigation were single-slice and helical multidetector row (1-256 slices). In Puducherry (Saravanakumar *et al.*, 2017) six CT scanners were used, while in Kerala (Huda and Mettler, 2011), 16 were used in eight main cities out of 13. QA and QC were done on all equipment in these studies. Some CT scanners have higher CTDI and DLP than others, indicating higher radiation output

Table 2: CTDI, DRL in pediatric CT (Huda and Mettler, 2011).

Study region	Age group	
	<1	1-5
Head	20 CTDI _v	38 CTDI _v
	352 DLP	505 DLP
Chest	7 CTDI _v	8 CTDI _v
	120 DLP	132 DLP
Abdomen	12 CTDI _v	14 CTDI _v
	252 DLP	270 DLP

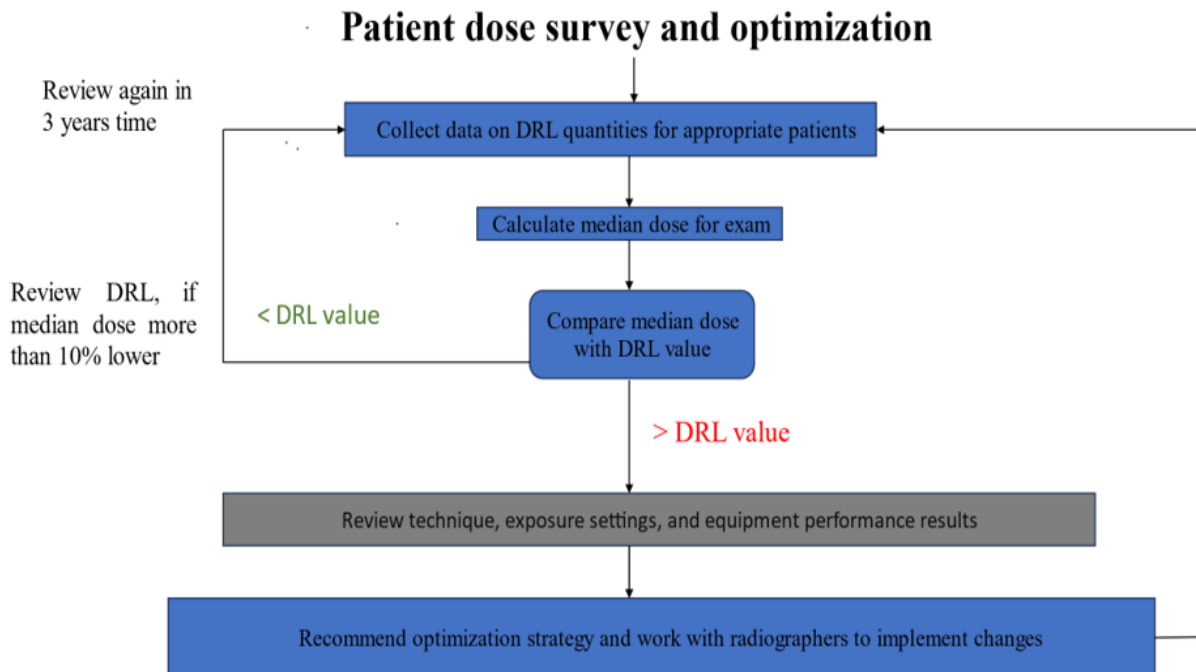


Figure 3: Optimization of radiation protection in digital radiology techniques.

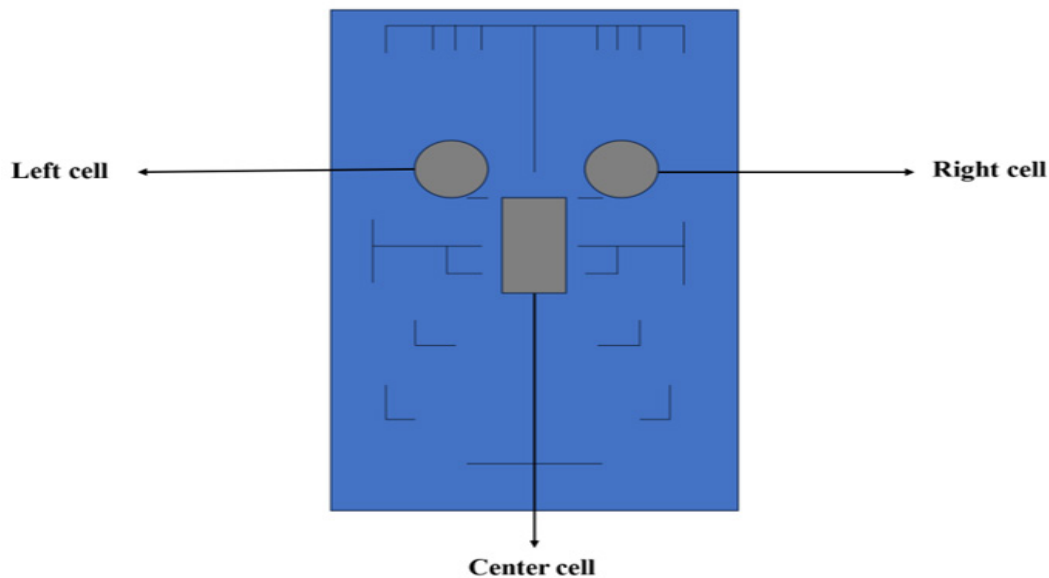


Figure 4: AEC sensor (Automatic exposure control).

due to operating parameters like pitch, kV, slice collimation, scan mode, slice thickness, measurement field, tube rotation, and couch increment. Periodic QA is recommended. CT scanners should choose slice thickness and scan parameters to reduce patient radiation.

Indian DRL establishment research is also published. One study described Tamil Nadu's regional pediatric CT dose (Huda and Mettler, 2011) in Table 2. That study found that the 75th percentile of DLP of infant head for 0-1 year olds is greater and lower than European PiDRL for 1-5 year olds, and for abdominal and chest operations is higher than European pediatric DRL for both age groups. This is largely owing to long scan times for both procedures and age groups. The age and weight-based protocol for pediatric CT examination for DRL comparison is lacking, according to this analysis.

Another one-month study at seven Kerala tertiary care institutions examined multidetector CT radiation doses by anatomical location. Single-phase head exams had a 75th percentile CTDI_v of 68.1 mGy and DLP of 1120 mGy/cm. The 75th percentile CTDI_v and DLP for single-phase abdomen examinations were 10.6 and 509.3; multiphase examinations were 14.6 and 2666.9; single-phase chest examinations were 23.4 and 916.7; multiphase chest were 19.9, 1737.6; and single-phase neck examinations were 24.9, 733.6 and 2076. Iterative reconstruction and automated tube current modulation are standard on all MDCT scanners. Despite greater image quality, MSCT's smaller pitch factor increases CTDI_v ($CTDI_v = CTDI_w / \text{pitch}$) (Huda and Mettler, 2011). DRL should be calculated independently for single- and multi-section research. Delay phases should be incorporated in multi-phase investigations.

CONCLUSION

The literature concludes that over past few years, the establishment of Diagnostic Reference Level in India have not considerably increase. There are only few studies published on DRL which is only from south India. There should be awareness and knowledge of DRL in public and private hospitals. Radiation safety in diagnostic radiology is important, not only because of regulatory requirements but also because of personal and patient consideration. Professionals must agree on the collection of DRL data to establish DRL values and optimize the dose. Current CT scanning technology uses two measures to estimate patient radiation exposure: CTDI_v and DLP. In the current review, significant dose variations were noted, and these variations were due to differences in scanning protocols and scanning-related parameters. Standardization of protocols and optimizing exposure parameters are necessary. DRL is a useful tool for continuous improvement of clinical practice. Radiologists and technologists need to be aware of local dose variations within their department as compared with national and international DRLs.

ABBREVIATIONS

CT: Computed Tomography; **CAT:** Computed Axial Tomography; **MDCT:** Multi-Detector Computed Tomography; **DRL:** Diagnostic Reference Level; **DLP:** Dose Length Product; **CTDI:** Computed Tomography Dose Index; **AEC:** Automatic Exposure Control; **kVp:** Kilovoltage Peak; **ALARA:** As Low As Reasonably Achievable; **AERB:** Atomic Energy Regulatory Board; **NABH:** National Accreditation Board for Hospitals and Healthcare Providers; **ICRP:** International Commission on Radiological Protection; **WHO:** World Health Organization; **PMMA:** Polymethylmethacrylate; **MSCT:** Multi-Slice Computed Tomography; **LDCT:** Low-Dose Computed Tomography; **CNN:**

Convolutional Neural Network; QA/QC: Quality Assurance/Quality Control; NDRL: National Diagnostic Reference Level.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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