Establishing Local Diagnostic Reference Levels (LDRL) for Brain and PNS CT Scans at Zayed Military Hospital, Abu Dhabi

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ABSTRACT
Computed Tomography (CT) is a vital diagnostic tool in modern medicine, offering detailed imaging but also contributing significantly to patient radiation exposure, necessitating careful dose management. Diagnostic Reference Levels (DRLs) are benchmarks designed to optimize radiation doses while maintaining diagnostic quality. The study establishes local diagnostic reference levels (LDRLs) for adult patients having brain and paranasal sinus (PNS) CT scans at Zayed Military Hospital (ZMH) in Abu Dhabi. Data collected from June to December 2023 included 30 brain CT scans and 30 paranasal sinus (PNS) scans. The median values result for head CT were CTDIvol = 37.43 mGy and DLP = 611.28 mGy .cm; for sinus CT, CTDIvol = 1.8 mGy and DLP = 25.3 mGy.cm. These criteria align with the Initial UAE Federal Authority for Nuclear Regulation (FANR) and international standards, contributing to improved radiation dose management while maintaining diagnostic quality.

1. Introduction

Computed tomography (CT) is recognized for its ability to provide detailed diagnostic images, although it is associated with significant radiation exposure to patients. To ensure patient safety, adherence to radiation protection principles justification, optimization, and limitation is essential when utilizing CT imaging [1-4]. The International Commission on Radiological Protection (ICRP) first emphasized the optimization principle in 1991 as a cornerstone of radiological safety, particularly in diagnostic imaging [5-8]. In 1996, the ICRP introduced Diagnostic Reference Levels (DRLs) as a critical strategy for managing ionizing radiation in medical imaging practices, including CT scans. DRLs are vital benchmarks for optimizing radiation exposure, offering guidance to ensure patient doses remain within acceptable ranges during diagnostic and interventional procedures. These reference levels help evaluate whether the median dose for a specific imaging procedure and patient group falls within the expected range under standard conditions or deviates significantly [6, 9-10]. The UAE's Federal Authority for Nuclear Regulation (FANR), in its Regulation 24 (version 1), characterizes the Diagnostic Reference Level (DRL) as a benchmark utilized in medical imaging to determine whether, under standard conditions, the dose delivered to the patient, or the amount of radioactive material administered during a specific radiological procedure is exceptionally high or low for that procedure[11] . During 2014/2015, the Federal Authority for Nuclear Regulation (FANR), in collaboration with the International Atomic Energy Agency (IAEA), launched a project to establish National Diagnostic Reference Levels (NDRLs). Participating institutions included hospitals under the Dubai Health Authority and Abu Dhabi Health Services. Data on Diagnostic Reference Levels (DRLs) were collected for dental radiography, mammography, computed tomography (CT), and nuclear medicine procedures. In 2017, the FANR Radiation Protection Committee approved the implementation of the initial NDRLs in healthcare facilities across the UAE. The establishment of NDRLs involved setting preliminary DRLs as a reference point for healthcare providers, both private and governmental, to develop facility-specific DRLs. These initial DRLs encompassed four CT examinations, with reference values for brain scans (871 mGy.cm) and brain scans with contrast (1071 mGy.cm). This initial report focused solely on Dose-Length Product (DLP) data and required all healthcare organizations to develop their own DRLs [12]. DRLs for CT examinations are established based on two key dose metrics. The first metric, the volume Computed Tomography Dose Index

($CTDI_{vol}$), quantifies the average radiation dose absorbed within the scanned region and represents the dose delivered per gantry rotation, expressed in milligray (mGy). The second metric, the Dose Length Product (DLP), reflects the total radiation dose absorbed by the patient, calculated as the product of the scan length and the $CTDI_{vol}$. This is measured in milligray-centimeters (mGy.cm) [5, 7, 13-14]. These parameters are foundational tools for dose assessment and optimization in CT imaging [15-16] . This study focuses on establishing local diagnostic benchmarks for CT protocols, contributing to improved radiation dose management in line with both national and international standards. This study aims to establish Local Diagnostic Reference Levels (LDRLs) for brain and PNS CT protocols at ZMH and validate them with national and international standards.

2. Materials and Methods

Data Collection:

Data were collected from June to December 2023, focusing on adult patients (>16 years, 75±10 kg) undergoing brain and PNS CT examinations. Relevant patient demographics, including age, gender, weight, and height, along with scan exposure parameters such as kV, mA, mAs, and exposure time, were extracted from Digital Imaging and communications in Medicine (DICOM) images to ensure accurate analysis. Ethical approval for this study was obtained from the Ethics and Research Committee of Zayed Military Hospital, ensuring compliance with ethical standards and protocols for conducting research involving patient data.

CT Scanner Specifications:

CT scans were performed using a General Electric (GE) Revolution Apex 512-slice scanner (2022 model) with a maximum tube current of 1300 mA and 140 kV.

Statistical Analysis:

Descriptive statistics (minimum, maximum, mean and standard deviation) were calculated to establish LDRLs. The median value was chosen as the LDRL benchmark, adhering to ICRP Publication 135 recommendations [15].

3. Results

Patient Demographics and Exposure Parameter:

The study analyzed data from 60 patients who underwent CT examinations at Zayed Military Hospital (ZMH), comprising 30 brain CT and 30 paranasal sinus (PNS) CT scans. The mean age of patients undergoing brain CT scans was 38 years (SD ±16), while for PNS CT scans, the mean age was slightly lower at 34 years (SD ±12). The cohort predominantly consisted of male patients, reflecting the demographic characteristics and utilization trends observed at ZMH. The current tube modulation was consistently activated for both examinations. The exposure parameters for the brain protocol were as follows: kV 140 and automatic mAs ranging from 164 to 304. For the paranasal sinuses (PNS) protocol, a low-dose protocol was applied with kV 100 and automatic mAs ranging from 16 to 20. The low-dose CT protocol for paranasal sinuses significantly reduces radiation exposure compared to standard protocols, aligning with ALARA principles; the low-dose protocol employs 100 kV and an automatic mAs, achieving substantial dose reduction. Despite these lower settings, image quality remains diagnostically acceptable, as confirmed by radiologist approval. This protocol demonstrates the effectiveness of advanced CT technologies, such as tube current modulation and iterative reconstruction, in optimizing patient safety without compromising diagnostic accuracy.

Radiation Dose Metrics:

The radiation dose metrics were analyzed using the CT Dose Index ($CTDI_{vol}$) and Dose Length Product (DLP) for both brain and PNS CT examinations. The calculated values represent the 50^{th} percentile of dose distributions, aligning with international standards for Local Diagnostic Reference Levels

(LDRLs) [15].

Table 1. The median and standard deviation of brain and PNS.

LDRL		
Protocol	Brain	PNS
Median ± SD (CTDI $_{vol}$ mGy)	37.43±6.05	1.81±0.25
Median ±SD (DLP mGy.cm)	611.28±108.7	25.21±4.06

Table 1 presents Local Diagnostic Reference Levels (LDRL) for brain and PNS imaging protocols, highlighting the median and SD values for two key parameters: $CTDI_{vol}$ and DLP. The table compares radiation dose metrics for brain and paranasal sinuses (PNS) CT protocols, showing median and standard deviation (SD) values for $CTDI_{vol}$ and DLP. The brain protocol has a significantly higher $CTDI_{vol}$ (37.43 ± 6.05 mGy) and DLP (611.28 ± 108.7 mGy.cm) due to the need for detailed imaging of dense and complex structures, resulting in greater variability likely influenced by patient-specific factors. In contrast, the PNS protocol demonstrates effective dose optimization with a low $CTDI_{vol}$ (1.81 ± 0.25 mGy) and DLP (25.21 ± 4.06 mGy.cm), reflecting standardized low-dose imaging for superficial structures. The brain protocol's higher variability suggests opportunities for further refinement, while the PNS protocol exemplifies the ALARA principle, ensuring minimal radiation exposure without compromising diagnostic quality.

Comparative Analysis:

A comparative evaluation of the established LDRLs against national and international standards highlights the hospital's alignment with regulatory guidelines and global best practices. Table 2 summarizes the comparison. Figure 1 demonstrates the comparison of this study with other studies.

Table 2. Comparison between current study with national and international studies.

Region	Examination	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)
ZMH (Current)	Brain CT	37.4	611.2
UAE (FANR 2018)	Brain CT	N/A	781
UK (2022)	Brain CT	47	790
Canada (2022)	Brain CT	44	815
Australia (2020)	Brain CT	52	770
ZMH (Current)	PNS CT	1.8	25.3
UK (2022)	PNS CT	12	30

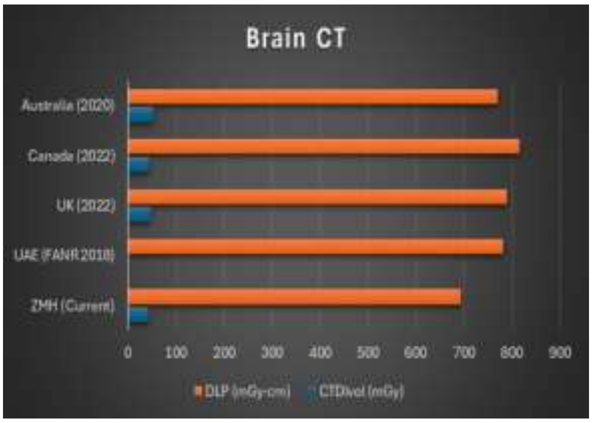

Figure 1. Comparison between current study (ZMH) and other studies

A comparative evaluation of the established Local Diagnostic Reference Levels (LDRLs) against national and international standards highlights the hospital's alignment with regulatory guidelines and global best practices. The radiation doses for Brain CT at ZMH closely align with the UAE Federal Authority for Nuclear Regulation (FANR) standards [17] . They are comparable to values reported in the UK, Canada, and Australia[5]. For Brain CT, the ZMH protocol achieves a $CTDI_{vol}$ of 37.4 mGy and a DLP of 611.2 mGy.cm, which are lower than the DLP values reported in the UAE (781 mGy.cm), UK (790 mGy.cm), Canada (815 mGy.cm), and Australia (770 mGy.cm). These lower values at ZMH suggest effective dose minimization while maintaining diagnostic image quality. Differences in DLP may be influenced by variations in scan length, imaging protocols, and patient demographics. For PNS CT, ZMH achieves a $CTDI_{vol}$ of 1.8 mGy and a DLP of 25.3 mGy.cm, significantly lower than the UK's reported $CTDI_{vol}$ of 12 mGy and DLP of 30 mGy.cm, ZMH's imaging protocols for brain and paranasal sinus (PNS) examinations demonstrate a superior commitment to dose optimization, emphasizing patient safety without compromising diagnostic quality. The brain protocol employs a tailored approach with automated adjustments, ensuring optimal imaging while avoiding unnecessary exposure. Similarly, the PNS protocol utilizes advanced low-dose tools to significantly reduce radiation, which is particularly effective in minimizing dose to sensitive areas such as the eyes. These protocols benefit from the advanced features of the CT machine, including sophisticated tube modulation and dose reduction technologies designed to minimize radiation to vulnerable tissues while maintaining image reliability. Radiologist-approved image quality confirms the efficacy of these protocols, highlighting their ability to balance diagnostic accuracy and radiation safety. ZMH's approach reflects a forward-thinking integration of cutting-edge technology and clinical expertise, addressing regional variations in imaging practices and setting a benchmark for excellence. Further exploration of these protocols globally could establish best practices for consistent and safe dose optimization, benefiting patients and advancing imaging standards worldwide.

4. Discussion

This study shows Brain CT protocols at ZMH achieve $CTDI_{vol}$ and DLP values consistent with UAE FANR recommendations and comparable to those reported in the UK, Canada, and Australia, reflecting a balanced approach to maintaining diagnostic quality while minimizing radiation exposure. The notably lower values for PNS CT emphasize ZMH's proactive implementation of dose-reduction measures, prioritizing patient safety. Observed variations in dose metrics across regions underscore the impact of differences in imaging protocols, scan lengths, and the adoption of advanced technologies, such as iterative reconstruction and automated exposure control. Furthermore, the CT machines utilized at ZMH are equipped with advanced specifications, including organ-based modulation that selectively reduces radiation exposure in sensitive areas such as the thyroid gland and orbits. These technologies further enhance patient safety by tailoring radiation doses based on anatomical considerations. These findings highlight the significance of region-specific customization in imaging practices to accommodate local clinical needs and technological capabilities. Additionally, the study identifies areas for improvement, particularly in high-dose protocols, by adopting advanced techniques and patient-specific approaches to optimize radiation doses without compromising diagnostic efficacy.

5. Conclusion

This study confirms that ZMH's LDRLs are well-aligned with international and national standards, reflecting a strong commitment to radiation safety and effective dose management. The hospital's protocols achieve radiation doses that are lower or comparable to international counterparts, particularly in the brain and PNS CT imaging, demonstrating the successful implementation of dose-reduction strategies. Variations in dose metrics across regions point to differences in imaging practices and technological utilization, reinforcing the need for tailored protocols that balance safety and diagnostic requirements. While ZMH has significantly progressed in optimizing radiation doses, further enhancements can be achieved through advanced imaging techniques and individualized protocols. These findings underscore the importance of ongoing evaluation and refinement of imaging practices to maintain high patient care and diagnostic accuracy standards.

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