Computed Tomography Diagnostic Reference Levels in Middle Eastern Healthcare: A Systematic Review

Abdul Alim [1,2], Leong Sook Sam[2], Omar Adil M. Ali[1]

[1] Department of Radiological Imaging Technologies, Cihan University-Erbil, Erbil, Kurdistan Region, Iraq

[2] Center for the Study of Medical Imaging, Faculty of Health Science, Universiti Teknologi Mara, Malaysia

***Abstract*— Continuous advancements in computed tomography technology have improved image quality, reduced scanning times, and expanded the range of applications of Computed tomography (CT). As a consequence, the quantity of CT examinations performed has increased steadily over the last several decades. Therefore, the increase in the population's exposure to ionizing radiation results in an increased risk of cancer. The diagnostic reference level (DRL) is one method for optimising radiation protection, as recommended by the ICRP. The diagnostic reference level (DRL) is one of the tools for the optimization of radiation in CT. The goal was to identify the reasons and extent of differences in radiation doses reported in studies for the same type of CT scan across different countries in the Middle East. This review was conducted according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA). The literature search was conducted in PubMed, and Google Scholar up to 16 Feb 2024. The study revealed that the significant variation in dose across different countries in the Middle East could be attributed to differences in patient body sizes, technical parameters, and the various CT facilities. Regulatory bodies need to embrace and enforce DRL concepts within their facilities to reduce the significant variation in doses and a globally accepted standard of DRLs should be developed to make a meaningful comparison with international bodies.**

***Index Terms*— Computed Tomography (CT), Computed Tomography Dose Index Volume (CTDIvol), Dose Length Product (DLP), Dose Reference Level (DRL),International Commission of Radiation Protection (ICRP).**

I. INTRODUCTION

Continuous advancements in CT technology, such as iterative reconstruction systems, artificial Intelligence (AI) and deep learning technologies, spectral imaging with dual-energy CT (DECT), and photon-counting CT have improved image quality, reduced scanning times, and expanded the range of applications of CT(Counseller & Aboelkassem, 2022; A. AGOSTINI et al., 2022; Barragán-Montero et al., 2021; Hsieh & Flohr, 202; Heseltine et al.; 2020;). Consequently, there has been a consistent increase in the number of CT procedures performed over the past few decades(Smith-Bindman et al., 2019). Because CT scans use high radiation doses, they represent 11% of all radiological procedures and provide almost 70% of the overall radiation exposure associated with medical conditions. (Cao et al., 2022; Paulo et al., 2020). The growing population's exposure to CT scans leads to an increased risk of cancer (Abalo et al., 2021; Salih & Darogha, 2017). Reducing radiation dose in CT scans is a critical concern due to the potential health risks associated with ionizing radiation exposure. In CT scans, a combination of advanced technologies and diverse strategies for dose reduction are utilized to minimize radiation exposure while maintaining diagnostic accuracy (Dieckmeyer et al., 2023; Gottumukkala et al., 2019). Three fundamental ideas of radiation protection were defined by the International Commission on Radiological Protection (ICRP): dose limitation, optimisation, and justification(ICRP publication 103, 2007). The diagnostic reference level (DRL) is one of the methods for optimising radiation protection, as recommended by the ICRP. DRL is determined as the third quartile of the medians of DRL quantity at CT facilities in a country or region. DRLs are a significant tool for dose monitoring and reducing dose variance, particularly when doing the same scan at several CT sites. DRLs are suggestions for acceptable doses to ensure adequate image quality, which helps optimise radiation doses (ICRP Publication 135, 2017). Various professional organizations and regulatory bodies have expressed support for these guidelines, underscoring their significance in ensuring optimal radiation exposure for patients (IAEA & WHO, 2012; WHO (2016), n.d.). Despite widespread regulatory requirements and considerable attention on this subject, the majority of systematic reviews concerning Diagnostic Reference Levels (DRLs) stem from Europe. Notably, there is a lack of systematic reviews addressing healthcare practices related to DRLs in Middle Eastern countries. In Middle Eastern nations, established national dose reference levels for head, chest, and abdomen CT scans were systematically examined in this review. The objective of this research endeavor was to ascertain the factors contributing to variations in patient dose for identical CT procedures among different Middle Eastern countries. In the subsequent sections of this paper, Dose descriptors for DRL, the methodology employed in the systematic review, the obtained results, and the comprehensive conclusions drawn from the analysis will be thoroughly discussed and presented.

II. DOSE DESCRIPTORS FOR DRL

Computed Tomography Dose Index Volume (CTDIvol) and

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Computed Tomography Dose Length Product (DLP) are two parameters utilised to establish DRL in CT. Two polymethylmethacrylate cylindrical phantoms, often known as acrylic or Lucite, are utilised to measure the CTDIvol. Head phantoms with a diameter of 16 centimeters and body phantoms with a diameter of 32 centimeters are utilised to measure the scanner output for CT scans in adult patients. CTDIvol does not represent the effective dosage received by the patients but can measure the level of radiation released from the CT scanner and compare scanning protocol between or within CT facilities (Cody et al., 2011a). It is displayed on the CT scanner console both before and after a scan.

DLP is a quantity that takes into account both CTDIvol and the scan length for a given patient. The cumulative DLP for the entire examination is utilized as a DLP since it represents the overall amount of ionising radiation for an entire examination (Cody et al., 2011a).

Commonly, DRLs are referred to as the 3rd quartile of CTDIvol or DLP for a patient undergoing a CT scan.

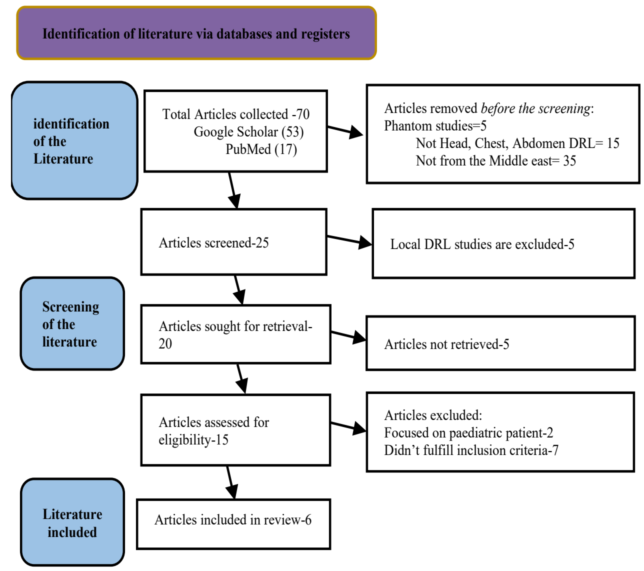

Fig. 1. The flowchart according to PRISMA guidelines; DRL, Diagnostic reference level.

III. METHOD

This review was conducted according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Page et al., 2021). Thorough literature searches from 2010 to 2024 were conducted across various databases, including Google Scholar, and PubMed. The search strategy involved utilizing appropriate Boolean operators and incorporating keywords such as "Reference level", "Diagnostic reference levels," and "DRL", along with terms related to CT scans such as "CT", "computed tomography," or "computed axial tomography. This search strategy was implemented for every Middle Eastern country individually. Emphasis was placed on examining titles and abstracts of articles published until February 2024.

All chosen papers were uploaded to the Mendeley reference manager tool to identify duplicates and screen titles and abstracts. Any duplicates found were subsequently removed from the review.

This study conducted a systematic review of the DRL study, which centered on routine CT examinations of the abdomen, brain, and chest in Middle Eastern healthcare. Only the National Diagnostic Reference Levels (NDRL) studies were considered in this analysis. The 75th percentile values of CTDIvol and DLP were obtained as DRL metrics (ICRP Publication 135, 2017).

The exclusion criteria for this review included contrast studies and procedures requiring special protocols, including angiographies, colonography, urography, cardiac and extremity scans. Pilot studies and local DRLs are not included in this review. DRLs based on clinical indications are also not included in this review as the same anatomical region can have more than one clinical indication and this doesn't shoot in this study.

IV. RESULT AND DISCUSSION

A comprehensive literature search yielded twenty-five articles related to DRL of CT studies in the Middle East. Upon assessment of abstracts from nineteen of these studies, they were found to not meet the inclusion criteria and were consequently excluded. Following full-text screening, six articles were deemed suitable for inclusion in the review.

The DRLs for various anatomical regions in Middle Eastern countries are documented in Table-1. This table shows the DRL values of all three body (head, chest, and abdomen) regions based on CTDIvol and DLP of six Middle Eastern countries.

TABLE I
DRL VALUES FOR MIDDLE EASTERN COUNTRIES

Country	Brain		Chest		Abdomen-Pelvis	
	75th percentile		75th percentile		75th percentile	
	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)
Iran (Najafi et al., 2015)	43	700	22	290	10	550
Saudi Arabia (NDRL: 2.0, 2022)	55	1026	12	430	14	706
UAE (Abuzaid et al., 2020)	48	818	10	276	14	811
Turkey (Ataç et al., 2015)	66	810	11.6	289	13	204
Jordan (Radaideh et al., 2023)	64	1223	17	582	18	923
Egypt (Salama et al., 2017)	30	1358	22	420	31	1323
USA (Morin et al., 2021)	56	962	12	443	16	781

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The American Association of Physicists and Medicine (AAPM) and the ICRP advise conducting annual reviews of CT scan protocols for individual regions or countries. CT DRLs offer benchmarks for radiation doses of different CT procedures and they shouldn't be rigidly adhered to as limits or targets. They should guide optimization efforts, with the ultimate aim of minimizing radiation exposure while preserving diagnostic image quality. DRLs may not be universally applicable due to variations in patient demographics, imaging methodologies, and equipment standards across different geographic regions.

A thorough literature review was conducted concerning the NDRLs associated with CT procedures performed on the head, thorax, and abdomen in Middle Eastern nations. Furthermore, an investigation was conducted into the methodology of established CT DRLs in adults. DRLs that have been established were calculated using a range of radiation dosage parameters. CTDIvol and DLP are commonly reported indices because of the widespread usage of multislice scanners that operate in helical mode (Cody et al., 2011b). Modern scanners are now designed to show the CTDIvol for standardising indices, as stated in the AAPM report (AAPM REPORT NO 96, 2008; Benzehoua et al., 2023). This review specifically focused on studies that selected CTDIvol and DLP as criteria for determining DRLs. CTDIvol and DLP were selected because they are standard dose indices, simplifying the review process.

A study from Turkey (Ataç et al., 2015) found CTDIvol and DLP values for CT brain were 66 mGy and 810 mGy.cm, respectively, when establishing DRLs. In contrast, a study from Egypt (Salama et al., 2017) reported CTDIvol and DLP values of 30 mGy and 1358 mGy.cm for brain scans. These two studies show significant variation in CTDIvol and DLP measurements. The CTDIvol in Turkey is due to the use of higher scanning parameters (kV, mAs, or exposure time), and lower CTDIvol head scans in Egypt due to using higher pitch. In Egypt, the DLP for brain scans is higher than in other nations as a result of the wider scanning range. UAE has the lowest CTDIvol and DLP for Chest CT which are 10 mGy and 276 mGy.cm respectively. The study suggested that the UAE's dose index appears to be lower than other studies due to the implementation of standardized protocols. Furthermore, implementing recently developed scanners produced exclusively by a single company (GE) may potentially enhance the consistency of radiation outputs by utilising similar protocols and technologies. In Egypt (Salama et al., 2017), the Abdomen CT scan exhibits the highest CTDIvol and DLP values, measuring 31 mGy and 1323 mGy.cm, respectively. The higher DRL values for CT abdomen observed in Egypt to other nations could be attributed to higher median patient weights and not following the guidelines of optimisation of the protocol. Compared to the recently established radiation dose standards for adult patients in the USA, most of the countries included in this study exhibit consistency in CTDIvol values for adult CT procedures but show inconsistencies in DLP values in Fig.1 & 2. Variations in patient demographics and scan length can be the cause of these discrepancies.

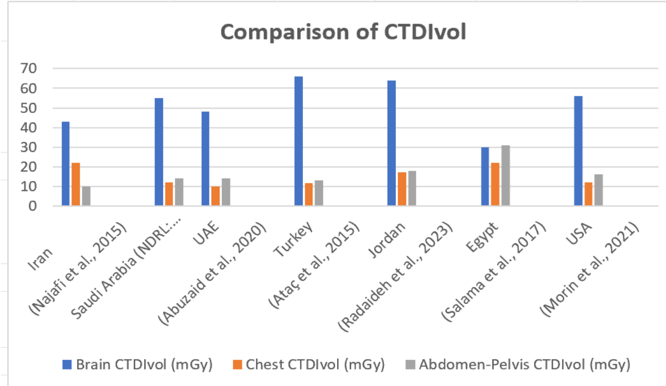

Fig. 1. Comparison of CTDIvol of Middle Eastern countries with USA

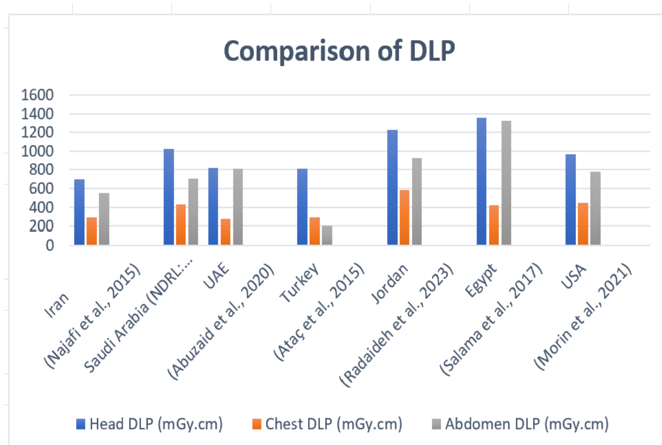

Fig. 2. Comparison of DLP of Middle Eastern Countries with USA

Conclusion

DRLs in Middle Eastern nations are often established at the 75th percentile of the median patient dose distribution in healthcare institutions and serve as the dose descriptor. The primary objective of implementing DRLs within a country is to mitigate the variability in dose levels, standardize practices, and enhance diagnostic efficacy. The significant variation in dose across different countries in the Middle East may stem from differences in patient body sizes, technical parameters, and the various CT facilities involved in the studies. Regulatory bodies need to embrace and enforce DRL concepts within their facilities to reduce the significant variation in doses within and between countries. Elevating radiographers' awareness of the strategies for mitigating radiation exposure during medical imaging procedures can result in a noteworthy reduction in variations in DRLs. The comparison of DRLs is also difficult as there are no international standard DRLs. To facilitate precise comparisons with international DRLs, a globally accepted standard methodology that includes dose-measuring methods, scanning strategies, patient demographics, and a DRL percentile must be established immediately.

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