Drug, Healthcare and Patient Safety

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REVIEW

Computed Tomography Diagnostic Reference Levels Worldwide and in Jordan: Implications for Patient Dose Reduction

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Abstract: Computed tomography (CT) contributes substantially to medical radiation exposure, making diagnostic reference levels (DRLs) essential for dose optimization and patient protection. This narrative review summarizes international CT DRL practices and examines the current status of DRL development in Jordan. Published studies and key guidance documents addressing adult and pediatric CT DRLs, including CTDIvol, dose-length product (DLP), and size-specific dose estimate (SSDE) where available, were reviewed to identify common implementation approaches, frequently used dose metrics, and evidence gaps relevant to Jordan. The reviewed literature shows marked inter-country variation in DRL methodology, updating cycles, and regulatory integration. In Jordan, available studies demonstrate useful local and multicenter data, but routine CT practice still lacks a unified national DRL framework. Reported Jordanian values also show inter-institutional variability, highlighting the need for standardized data collection, regular auditing, and coordinated national oversight. Establishing national DRLs based on transparent methodology and periodic revision would strengthen radiation protection, improve protocol consistency, and support safer CT practice in Jordan.

Keywords: computed tomography, diagnostic reference levels, radiation protection, patient safety, Jordan

Introduction

Computed Tomography (CT) has emerged as an essential diagnostic instrument in contemporary medicine, owing to its fast capture of high-resolution images and extensive clinical uses.[1] The growing utilization of CT imaging has elicited apprehensions about patient exposure to ionizing radiation. To mitigate these issues, Diagnostic Reference Levels (DRLs) have been instituted as an effective mechanism for optimizing radiation dosage, ensuring that patient exposure is minimized to the lowest extent feasible without sacrificing diagnostic integrity.[2,3] The global application and regulation of CT DRLs exhibit considerable variation, influenced by disparities in healthcare systems, technology progress, and regulatory structures. Numerous nations have established national diagnostic reference levels (DRLs) informed by demographic data, imaging methodologies, and equipment functionalities, adhering to guidelines from entities such as the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA).[4,5]

Diagnostic reference levels (DRLs) are not dose limits. DRLs are advisory benchmarking values used in medical imaging to help departments identify when the typical dose for a standard examination is unusually high or unusually low, so protocols can be reviewed and optimized; they are not intended for strict application to an individual patient. By contrast, dose limits are regulatory maximum doses used mainly for occupational and public exposure, and they generally do not apply to patients undergoing medically justified imaging or treatment, where protection is based on justification and optimization rather than fixed dose caps. In Jordan, an increasing emphasis on radiation protection and quality assurance in medical imaging has initiated endeavors to create and revise national CT diagnostic reference levels (DRLs).[6–8] This analysis seeks to assess the

https://doi.org/10.2147/DHPS.S595721
Received: 12 January 2026
Accepted: 22 April 2026
Published: 2 May 2026

present situation of CT DRLs globally and to contextualize Jordan's activities within an international framework.[9,10] The review aims to enhance radiation protection standards in Jordan and promote the advancement of safe imaging procedures by examining commonalities, discrepancies, and opportunities for improvement.

Overview of Computed Tomography (CT)

CT is a medical imaging technique that use X-rays to produce cross-sectional images of the human body, offering fine anatomical details. The images are derived from X-ray attenuation data obtained as the beams traverse various human tissues.[11–15] CT employs a revolving X-ray tube and a number of detectors that around the subject to obtain numerous projections from various angles. The data are subsequently reconstructed into 2D or 3D images utilizing technologies such as filtered back projection or iterative reconstruction. Contemporary CT scanners have multi-detector rows, facilitating reduced scan durations and finer slices, hence enhancing spatial resolution and diagnostic accuracy.[16–18] The principal benefit of CT compared to traditional radiography is its capacity to provide cross-sectional images, thereby eliminating anatomical superimposition. CT is particularly adept in identifying small lesions, internal hemorrhaging, and organ anomalies that may remain undetected on conventional X-rays.

This diagnostic benefit is accompanied by an increased radiation dosage, rendering dose optimization a critical issue in CT practice. Recent improvements in CT technology, such as dual-energy CT, automated exposure control (AEC), and sophisticated reconstruction techniques, have markedly reduced patient dose while preserving image quality.[19]

Clinical Applications of CT

Computed Tomography (CT) is extensively utilized in practically all medical fields owing to its rapidity, precision, and capacity for precise viewing of internal anatomy. It serves a pivotal function in the emergency department, diagnostic assessment, and cancer. In neurological imaging, computed tomography (CT) is the primary modality for evaluating acute stroke, cerebral bleeding, and traumatic brain damage.[20,21] Computed tomography is extensively utilized in the thorax to assess pulmonary embolism, pulmonary infections, and for oncological staging. Abdominal and pelvic CT is crucial for the diagnosis of appendicitis, renal calculi, and abdominal tumors. CT angiography facilitates non-invasive evaluation of coronary artery disease in cardiac imaging.[22–24] Musculoskeletal CT offers enhanced bone visualization, especially in intricate fractures and spinal injuries. CT is frequently favored over alternative imaging techniques because of its superior spatial resolution, rapid acquisition, and capacity to produce three-dimensional reconstructions.[25] In comparison to MRI, it is more rapid and readily available, particularly in acute care environments.[26,27]

In Jordan, similar to numerous nations, computed tomography is progressively employed in emergency rooms and oncology treatments, mirroring global trends in high-dependency medical care. Nonetheless, its extensive application substantially increases population radiation exposure, becoming dose optimization a vital issue in contemporary CT practice.[28]

CT Utilization Trends and Expansion

CT was initially introduced in 1971 by Sir Godfrey Hounsfield and Allan Cormack, transforming diagnostic imaging. Initially, a 180-degree scan required around five minutes; contemporary scanners can now do a complete 360-degree rotation in less than 0.3 seconds, exhibiting significantly enhanced spatial and temporal resolution. In the last twenty years, progress has concentrated on enhancing image quality and speed while also optimizing radiation dosage through methods such as automatic exposure control, modulation of tube current and voltage, and iterative reconstruction algorithms.[20,29,30]

The rapid acquisition and elevated diagnostic yield of CT have resulted in its extensive utilization, especially in emergency contexts when prompt decision-making is essential. Global utilization has risen across both adult and pediatric populations.[31,32] Abdominal and chest computed tomographies are among the most commonly conducted examinations, particularly in acute care settings.[33] Throughout the COVID-19 pandemic, chest CT scans were often employed to evaluate lung involvement, resulting in a notable rise in utilization from 2020 to 2022.[34,35]

Nonetheless, this increase in utilization has prompted apprehensions regarding superfluous imaging. A substantial percentage of CT scans are deemed "low-value," providing minimal clinical advantage while escalating healthcare expenses and excessive radiation exposure.[36] In the mid-1990s, computed tomography constituted merely 4% of imaging operations yet was responsible for over 40% of the total diagnostic radiation exposure. Currently, computed tomography accounts for roughly 15% of diagnostic examinations yet contributes up to 75% of the overall radiation exposure in major hospitals.[37–39]

In Jordan, although national-level CT usage data is few, existing studies indicate a comparable rise. In public hospitals in northern Jordan, such as King Abdullah University Hospital (KAUH), CT scanners are extensively employed due to their scarcity; KAUH, for instance, maintains merely two CT scanners for a substantial regional population. Moreover, an increasing need on CT for urologic examinations such as CT-KUB, despite the adequacy of ultrasonography, indicates a transition towards greater reliance on cross-sectional imaging.[40]

Radiation Dose in CT Examinations

CT exposes patients to greater amounts of ionizing radiation than traditional radiography; unlike ultrasound and MRI, CT employs ionizing radiation, as previously mentioned. CT accounts for 50–75% of overall exposure in the healthcare sector. The effective dose for a single CT examination ranges from 2 to 20 mSv, depending on the type of exam. The typical effective doses are 2 mSv for head examinations, 10–13 mSv for trunk area investigations, and 4.5 mSv for lumbar spine examinations. The radiation dose in CT imaging is influenced by many technical and patient-specific factors.[41,42] Tube current (mA) and exposure duration, typically denoted as mAs, as the most significant exposure parameters. The dose increases linearly with mAs; although elevated values diminish image noise and enhance diagnostic clarity, they concurrently elevate patient exposure. Contemporary scanners employ automated exposure control (AEC) to dynamically change tube current, frequently attaining dosage reductions of 20–60% while maintaining image quality.[43]

A crucial element is pitch, which is defined as the table travel per gantry revolution divided by the entire collimation width. Elevated pitch values (>1) lead to reduced scan durations and diminished doses, whereas diminished pitch values (<0.5), employed in cardiac imaging, augment redundancy and hence heighten radiation exposure.[44] Detector configuration and slice thickness similarly affect dosage efficiency; thinner slices enhance spatial resolution but also elevate noise levels and typically necessitate increased mAs. Contemporary multislice detectors (eg., 64-slice) mitigate overbeaming and enhance dosage efficiency relative to previous models.[45,46] Image reconstruction techniques are essential for dose optimization. Conventional filtered back projection (FBP) necessitates elevated radiation doses for diagnostic clarity, but contemporary iterative reconstruction (IR) methods can diminish exposure by as much as 30% by algorithmic noise suppression. Patient posture is a frequently neglected factor influencing dosage variability.[47,48] Miscentering the patient elevates surface dosage by more than 20% and compromises imaging quality. This matter is particularly crucial in systems with AEC, as compensating for heightened noise may inadvertently increase exposure. Accurate positioning is crucial in dual-source CT systems, as gantry asymmetry exacerbates the consequences of improper centering. Finally, the scan range must be rigorously confined to the area of interest. Prolonging the scan beyond clinical requirement elevates radiation exposure without providing diagnostic advantage. A targeted range in pulmonary angiography can diminish exposure by as much as 48% while maintaining diagnostic efficacy.[49–51]

Comprehending these characteristics is crucial for enhancing CT protocols and reducing radiation hazards, especially in high-volume imaging facilities or areas with inadequate regulatory frameworks.[52] While individual CT scans present a very minimal risk, their cumulative effect on population radiation exposure is significant. Although constituting about 10–15% of all imaging operations, CT accounts for around 70–75% of the overall effective dose from medical imaging in numerous established healthcare systems.[53,54] This unequal contribution has generated much concern, especially as CT usage continues to rise in emergency, oncological, and pediatric contexts. The biological dangers linked to ionizing radiation from CT scans are predominantly stochastic, indicating that the likelihood of adverse effects (such as cancer or hereditary consequences) escalates with dosage, however there is no specific threshold beneath which the risk is nonexistent.[55] Thus, even little exposures from standard diagnostic imaging may progressively increase cancer risk among extensive populations, particularly with recurrent exposures. Children and younger patients are especially susceptible due to heightened tissue sensitivity and an extended lifespan during which radiation-induced cancers may arise.[56] Consequently, justification and optimization constitute the fundamental concepts of radiation protection in medical imaging, as delineated by the International Commission on Radiological Protection (ICRP).[57]

Justification necessitates that every CT examination provides greater diagnostic advantage than the associated radiation danger. Optimization necessitates that the dose be maintained at the lowest level reasonably attainable

(ALARA) while preserving diagnostic image quality. These criteria are not merely ethical imperatives but also crucial for sustainable healthcare practices in the context of increasing CT volumes and broadening clinical reasons.[58–60]

Review Methodology

Review Design

This article was prepared as a structured narrative review of computed tomography diagnostic reference levels (CT DRLs) worldwide, with focused appraisal of the available evidence from Jordan.

Search Strategy

Relevant literature and guidance documents were identified through searches of databases such as PubMed, Scopus, Web of Science, and Google Scholar, together with manual screening of reference lists from included articles. Search terms included combinations of "computed tomography", "CT", "diagnostic reference level", "DRL", "CTDIvol", "DLP", "SSDE", "radiation dose", "dose optimization", and "Jordan". The search covered publications up to 12 months.

Eligibility Criteria

Included sources addressed adult or pediatric CT DRLs, national or local DRL surveys, CT dose metrics such as CTDIvol, DLP, and SSDE, or international guidance relevant to dose optimization. Studies unrelated to CT DRLs, non-medical uses of the term DRL, duplicate reports, and papers without relevant-dose information were excluded.

Data Extraction and Synthesis

For each included source, the following information was extracted when available: country, year, study design, number of centers, patient population, examination type, reported dose metric, DRL basis or percentile, and key implementation gaps. Findings were synthesized narratively, with special emphasis on implications for developing national CT DRLs in Jordan.

Clarification of DRLs

Diagnostic reference levels are not dose limits for individual patients. Rather, they are investigation levels used to identify unusually high or unusually low radiation doses for standard procedures and to support optimization while maintaining diagnostic image quality.

Diagnostic Reference Levels (DRLs)

Concept and Purpose of DRLs

DRL is a benchmark dose value utilized to enhance radiation protection in medical imaging.[61] It is not a dosage restriction, but a pragmatic instrument that aids in identifying abnormally elevated patient doses during diagnostic and interventional radiological treatments.[62]

DRLs are generally established at the 75th percentile of dose distributions obtained from local, national, or regional data. This criterion enables facilities to evaluate their standard practices against a population-based benchmark.[63,64] If median dosages for conventional procedures consistently surpass the DRL, a review must be conducted to evaluate the necessity for optimization, ensuring diagnostic quality is not compromised. DRLs are often established at the 75th percentile of dose distributions obtained from standard-sized adult patients (70 ± 15 kg) to ensure benchmark applicability across facilities.[65] Moreover, European practice frequently designates the 50th percentile as a "achievable dose" level—an aspirational benchmark for well-functioning centers rather than a legal restriction. The European Commission's Radiation Protection 185 guidelines for diagnostic radiology advocate a dual-threshold approach, recommending the establishment of both reference and achievable values for CT exams to facilitate continuous optimization.[66]

DRLs are not relevant to individual patients and are not designed to delineate acceptable or unacceptable medical practice. They do not supplant clinical judgment, nor should they hinder the necessity of obtaining diagnostically adequate images. The objective is to maintain dosages at levels that are as low as reasonably achievable (ALARA),

 https://doi.org/10.2147/DHPS.S595721

while ensuring adequate image quality. DRLs are not applicable to radiation treatment; rather, they may pertain to imaging processes utilized during planning, simulation, or verification in radiotherapy.[2,67,68] The ICRP and IAEA offer guidance on the application of DRLs; however, the obligation to establish and revise DRLs rests with national authorities, including health ministries and professional radiology organizations.[2] DRLs must be customized to local practices and routinely updated as technology and clinical protocols advance.[69]

DRLs are often articulated by modality-specific dosage measurements. Regarding CT, and the application is a cyclical process. See Table 1.

Role and Purpose of DRLs in Radiation Protection

The implementation of DRLs is a crucial element of radiation protection protocols in medical imaging, designed to uphold the principle of optimization.[70,71] According to ICRP Publication 135, DRLs function as investigative thresholds rather than regulatory dose limits, aimed at identifying abnormally high radiation doses in standard diagnostic and interventional procedures. They encourage evaluation and possible remedial measures without undermining diagnostic effectiveness.[2,60]

Clinical Procedures for DRL Establishment

The establishment of DRLs commences with a precise and uniform definition of the clinical procedure.[68] Radiological examinations ought to be classified not alone by anatomical location (eg., head, chest, abdomen) but also by procedural parameters, such contrast utilization, number of imaging phases, or acquisition methodologies. This guarantees that DRLs are sufficiently specific for useful application in clinical audits and protocol optimization.[17,72]

Patient Selection and Data Collection for DRL Determination

The selection of patients is an essential phase. For adult populations, DRL data are often collected from standard-sized patients (70 ± 15 kg), but for pediatric applications, stratification by age or weight is crucial due to rapid developmental changes influencing body composition and radiation absorption.[5,73,74] Both prospective and retrospective data may be utilized, typically obtained from Picture Archiving and Communication Systems (PACS), Radiology Information Systems (RIS), dosage monitoring software, or organized manual surveys.[75,76] A minimum of 20 to 30 patient-dose entries per procedure per site is advised to guarantee statistical significance, with multi-center surveys favored for the establishment of national or regional DRLs.[77]

DRL Metrics and Benchmarking Practices

In CT, the predominant DRL metrics are the volume-weighted computed tomography dose index (CTDIvol, measured in mGy) and the dose-length product (DLP, expressed in mGy·cm). Various methods employ entrance surface dose (ESD), kerma–area product (KAP), or cumulative air kerma, contingent upon the imaging environment. Upon the accumulation of adequate data, the 75th percentile (third quartile) of the distribution of median dosages among facilities is computed.[78] This value constitutes the DRL, acting as a benchmark beyond which practices may be deemed non-optimized. Facilities

Table 1 Diagnostic Reference Levels (DRLs) Summary

Concept	Description
CTDIvol	Computed Tomography Dose Index – volume: Indicates the mean dose within the scanned volume (in mGy).
CTDIw	Weighted CTDI: Represents the mean dose across a single slice and is utilized to calculate CTDIvol by normalizing with pitch.
DLP	Dose-Length Product: Quantifies total radiation exposure during the scan duration (mGy·cm).
DRL Application Process	1. Gather data on patient doses 2. Determine DRL values 3. Employ them for dose optimization 4. Regularly update to align with best practices.
Purpose of DRLs	Serve as a feedback mechanism to ensure continuous improvement in quality assurance and patient safety.

https://doi.org/10.2147/DHPS.S595721

that routinely surpass the DRL are urged to examine probable factors, including excessive protocol complexity, obsolete equipment, or inadequate patient centering. Doses markedly below the DRL should prompt an evaluation of picture quality to confirm diagnostic adequacy.[2,70]

International Implementation and Variability in DRLs

Global experience demonstrates the extensive adoption and variety of DRL deployment. In the United Kingdom, Public Health England (PHE) set national diagnostic reference levels (DRLs) for adult head computed tomography (CT) at 47 mGy for CTDIvol and 790 mGy·cm for DLP, derived from a countrywide study of more than 47,000 CT examinations across 182 scanners.[79] A national DRL of 56.02 mGy (CTDIvol) and 1260.3 mGy·cm (DLP) for adult head CT was established in Uganda through a multicenter survey done across 13 institutions in partnership with the IAEA.[80,81] A 2024 systematic analysis from Saudi Arabia revealed CTDIvol values in the pediatric population ranging from 11.7 to 79.9 mGy, contingent upon age group and facility, underscoring the critical necessity for standardized DRLs in children to mitigate avoidable exposure and establish best practices.[82,83] See Figure 1.

Review, Publication, and Integration of DRLs Into Practice

Upon establishment, DRLs must be officially published, routinely reviewed (often every 3–5 years), and included into local and national quality control initiatives. Facilities are required to compare their standard median dosages with national or regional diagnostic reference levels (DRLs). In the absence of national DRLs, international guidelines from ICRP or IAEA should be utilized until local data is accessible.[2] The implementation and utilization of DRLs necessitate collaborative efforts among national health authorities, radiology associations, and healthcare institutions to guarantee safe, evidence-based, and uniform imaging techniques.[84]

Parameters Used in DRLs

The establishment of DRLs relies on standardized, measurable dose parameters that provide uniform comparison across clinical settings and patient demographics. In CT, the two primary metrics recommended for DRLs are the volume-weighted computed tomography dose index (CTDIvol) and the dose-length product (DLP).[85] These parameters constitute the foundation of national and international dose audits owing to their practicality, repeatability, and accessibility from practically all contemporary CT scanners.

The prevalent utilization of CTDIvol and DLP is primarily due to their uniformity across scanner manufacturers and their automatic production throughout the majority of CT procedures. These characteristics render them suitable for

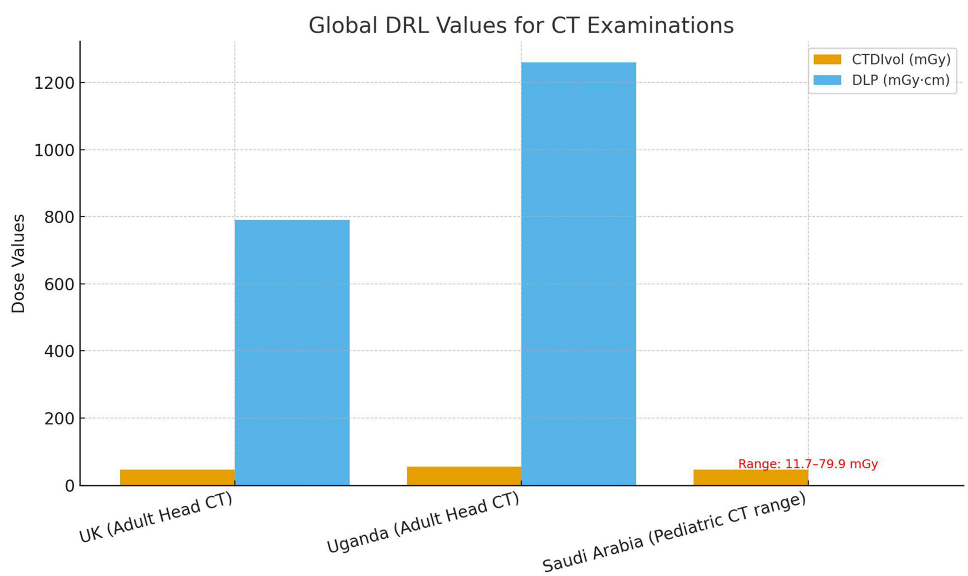

Figure 1 Global DRLs values for CT examinations.

integration into clinical audits, multicenter surveys, and dosage monitoring systems. In light of these constraints, alternative or supplementary metrics have been suggested.[86]

CTDIvol and the DLP

The CTDIvol, expressed in milligrays (mGy), denotes the mean radiation output per slice produced by a CT scanner, adjusted for the scanned volume.[87] It is obtained from standardized phantom measurements conducted under uniform acquisition conditions.[88] While CTDIvol is not a direct indicator of the radiation received by the patient or tailored to specific anatomy, it is nonetheless a crucial comparison parameter among scanners and procedures.[89]

The DLP, expressed in mGy·cm, is determined by multiplying CTDIvol by the scan duration. It offers an estimation of the overall radiation output for a complete examination and is regarded as a superior indicator of cumulative radiation exposure compared to CTDIvol alone.[86,90] A DRL founded on DLP functions as an effective benchmark for assessing overall scan output.

Size-Specific Dose Estimate (SSDE)

A notable new parameter is the SSDE, which modifies CTDIvol according to the patient's effective diameter.[91] SSDE, originally introduced by the American Association of Physicists in Medicine (AAPM Report No. 204),[92] is increasingly utilized in pediatric imaging and adult body CT, where patient size markedly influences radiation absorption. Its incorporation into DRL methods is currently restricted but is expanding, particularly in scenarios where accurate dose estimation is essential.[93] Nonetheless, similar to CTDIvol, it fails to include patient size, tissue weighting, or organ-specific sensitivity.[94]

Weighted CT Dose Index (CTDIw)

Historically, the CTDIw was utilized before the prevalent usage of CTDIvol. CTDIw, also quantified in mGy, integrates dose measurements from both central and peripheral areas of a phantom to more accurately reflect average dose distribution. Although predominantly obsolete in contemporary systems, CTDIw may nevertheless be cited for comparative analysis of legacy systems or for assessing older apparatus.[95]

The application of Effective Dose, quantified in millisieverts (mSv), is explicitly omitted from the estimation of DRLs. Effective Dose, designed for occupational exposure assessment, utilizes population-based risk models and organ weighting factors. The ICRP explicitly asserts that it is unsuitable for individual risk assessment, diagnostic decision-making, or quality control in medical imaging. Consequently, its application is confined to epidemiological modeling and population-level risk estimation.

In summary, although no one metric accurately measures patient-specific radiation exposure, CTDIvol and DLP continue to serve as the cornerstone of CT-based DRLs owing to their widespread accessibility, reliability, and incorporation into clinical practices. Supplementary measures such as SSDE provide advantageous enhancements, especially for size-adjusted dosage optimization, although have not supplanted traditional standards in the everyday application of DRLs.

International DRL Guidelines and Practices

The adoption of DRLs has emerged as a universally accepted approach for enhancing patient safety in medical imaging. International DRL programs enhance uniformity, safety, and quality assurance by establishing established benchmarks for radiation dosage levels.[96] The concept emerged in the 1950s through national surveys in the United States and the United Kingdom, which assessed patient dosage indicators to inform safer radiography practices.[70,97] The initial endeavors established the groundwork for formal DRL recommendations, codified in ICRP Publication 73 and subsequently articulated in ICRP Publication 135.[2]

Global Organizations and Their Roles in DRL Development

Global organizations are essential in formulating and distributing DRL guidelines. The ICRP provides a conceptual and methodological framework, highlighting Diagnostic Reference Levels (DRLs) as advising instruments for dose optimization. The International Atomic Energy Agency (IAEA) and the World Health Organization (WHO) assist member states by providing technical guidance, training, and facilitating surveys.[98–100] Professional organizations like the

American Association of Physicists in Medicine (AAPM) and the American College of Radiology (ACR) advocate for the implementation of Diagnostic Reference Levels (DRL), particularly in affluent healthcare systems.[2]

ICRP Guidelines and International Support for DRL Implementation

The ICRP, in Publication 135, characterizes DRLs as investigative thresholds—rather than regulatory limits—designed to stimulate the examination of abnormally elevated patient doses while maintaining diagnostic quality.[2] DRLs should be established at the 75th percentile of dose distributions obtained from representative clinical data, with modifications proposed every three to five years to align with technological advancements.[2] The IAEA provides support to countries via training workshops and organized survey instruments, underscoring that DRLs should align with local clinical practices instead than being directly imported from other countries.[101] It has facilitated national DRL development in more than 40 nations, particularly in low- and middle-income areas.[102] The WHO collaborates with the IAEA and ICRP to integrate DRL into national health policies and radiation safety frameworks, a cooperation especially vital in resource-constrained environments.[103] Organizations such as AAPM, ACR, and the European Radiation Dosimetry Group (EURADOS) enhance efforts by performing dose surveys, refining methods, and instituting quality assurance standards.[104–106] The ACR Dose Index Registry (DIR) aggregates data from numerous U.S. imaging sites, facilitating critical benchmarking for the creation and enhancement of DRLs.[107,108]

DRL Practices in the United Kingdom

The adoption of DRL differs globally, influenced by healthcare infrastructure, clinical practices, and regulatory frameworks. The United Kingdom possesses a developed DRL system overseen by the UK Health Security Agency (UKHSA).[109,110] National Diagnostic Reference Levels (NDRLs) are routinely revised based on data from national dose surveys conducted across numerous institutions. The current 2024 adult head CT diagnostic reference level is established at 47 mGy CTDIvol and 790 mGy·cm DLP, representing extensive clinical practice. Although advisory, these Diagnostic Reference Levels (DRLs) facilitate quality assurance in accordance with the UK's Ionising Radiation (Medical Exposure) Regulations (IR(ME)R), which require regular assessment and adjustment of protocols.[111]

DRL Development and Practice in Japan

In Japan, DRLs are managed by the Japan Network for Research and Information on Medical Exposure (J-RIME).[112] The 2020 DRLs derive from voluntary surveys of institutions nationwide and cover adult and pediatric CT procedures including head, chest, and abdomen. Japan establishes two dose levels: a 75th percentile DRL and an achievable dose at the 50th percentile, offering facilities both benchmarking and optimization objectives. For adult head CT, the DRLs are approximately 77 mGy CTDIvol and 1,350 mGy·cm DLP, contingent upon the equipment and scanning parameters utilized.[112] The Japanese method prioritizes institutional coordination and regular survey updates to ensure relevance.[113]

Emerging DRL Efforts in Saudi Arabia

While Saudi Arabia has yet to implement official national DRLs, scholarly efforts—especially in pediatric CT—indicate an increasing focus on dose optimization. A recent systematic study from 2024 examined CT dose data from various Saudi hospitals, uncovering significant diversity in pediatric head, chest, and abdominal CTDIvol values (11.7 to 79.9 mGy) according on age and institution. These findings underscore the necessity for standardized national benchmarks. The study, while presently advisory and research-oriented, adheres to ICRP methodology and may establish a basis for future regulatory DRL implementation in Saudi Arabia.[114,115]

Comparison of DRL Implementation Across Countries

While DRLs provide a universal foundation for dosage optimization, their application differs markedly among nations owing to variations in clinical practices, healthcare infrastructure, and regulatory contexts.[96] For example, the DRL for adult head CT in the UK is established at 47 mGy CTDIvol, whereas, in Japan, it is roughly 77 mGy CTDIvol. This gap indicates not just discrepancies in patient demographics and equipment but also methodological disparities in data collecting and dosage analysis.[116] The UK depends on extensive national audits organized by health agencies, while

Japan use volunteer surveys and reports both the median and 75th percentile for optimization purposes. Moreover, the legal position of DRLs varies; in the UK, they facilitate adherence to regulatory mandates under IR(ME)R,[117] but in Japan and Saudi Arabia, they are only advisory. The frequency of updates differs, as the UK frequently revises DRLs, with the most recent update in 2024, whilst Japan's last update occurred in 2020, and Saudi Arabia lacks explicit revision cycles. These variances emphasize the significance of context-specific formation of dose-response relationships while underscoring the necessity for worldwide standardization in dose monitoring procedures.

Relevance in Jordan (Lack of National DRLs in Jordan for Routine CT Imaging)

Despite global progress in Diagnostic Reference Levels (DRLs), Jordan has failed to establish official national DRLs for routine CT imaging, resulting in a significant deficiency in dose optimization and quality assurance protocols.[10] Nonetheless, several local studies indicate significant advancement toward these goals.

Despite the IAEA's recent "Rays of Hope" campaign facilitating PET-CT implementation in Jordanian public hospitals, it failed to build a national dose record or a DRL monitoring system. As a result, there is presently no clear national structure for the gathering of CT dosage statistics.[118]

A study conducted in 2023 by Radaideh et al assessed more than 2,000 CT scans from various hospitals in Jordan over the years 2021 and 2022. The suggested diagnostic reference levels (DRLs) for adult head computed tomography (CT) are 65.1 mGy CTDIvol and 945 mGy·cm DLP, significantly exceeding the reference limits established in the UK. The suggested DLP for chest-abdomen-pelvis CT was relatively lower. The values were derived from the 75th percentile of the gathered data, in accordance with ICRP recommendations.[10]

In a distinct study, Rawashdeh et al (2019) evaluated 228 cardiac CT examinations from seven hospitals in Jordan. The proposed diagnostic reference levels (DRLs) were reported as 47.7 mGy for CTDIvol and 1,035 mGy·cm for DLP, emphasizing a range exceeding fivefold in dose parameters among institutions. This inconsistency indicates a lack of cohesive national standards and underscores the necessity for centralized direction.[119]

Alzyoud, Kholoud et al conducted a study to aggregate and assess available data on diagnostic reference levels (DRLs) for conventional radiography and computed tomography (CT) in Jordan. A comprehensive search of major databases until June 2023, adhering to PRISMA principles, discovered seven suitable studies: one concerning conventional radiography, two pertaining to pediatric CT, and four related to adult CT examinations. These investigations employed multiple dose metrics, including entrance surface dose (ESD), effective dose (ED), volume CT dose index (CTDI_vol), dose-length product (DLP), and, in one pediatric research, size-specific dose estimate (SSDE). The results indicated considerable variability in diagnostic reference levels (DRLs), with adult chest radiography entrance surface doses (ESDs) spanning from 0.35 to 0.49 mGy and abdomen ESDs fluctuating significantly between 2.2 and 12.9 mGy. Pediatric dosages were often smaller but escalated with age. CT diagnostic reference levels (DRLs) were specified by anatomical area and age cohort, with adult chest CTDI_vol ranging from 12.9 to 16.6 mGy, with CAP examinations exhibiting DLPs as elevated as 1,150 mGy·cm.[9]

In comparison to international benchmarks, Jordanian radiography diagnostic reference levels (DRLs) were frequently elevated, although pediatric CT volume CTDI values were similar, but dose-length products (DLPs) generally beyond global standards. The research emphasized methodological discrepancies, insufficient consistent reporting, and a scarcity of national DRL data. The report concluded with recommendations to increase radiographer education on dose optimization, apply SSDE to consider patient size, and construct national DRLs in accordance with worldwide criteria to enhance patient safety and radiologic quality in Jordan.[9] See Figure 2.

Fragmented Practices and the Path Toward National DRL Development

These investigations indicate that although Jordanian institutions may generate high-quality dosage data, existing methods are scattered, reliant on specific facilities, and lack regulation. Motivated by global examples such as the UK's audits, Japan's tiered DRLs, and Saudi Arabia's academic initiatives, Jordan can establish its own DRL framework by standardizing CTDIvol and DLP reporting across institutions. See Table 2.

This research offers a timely synthesis of global DRL methodology and local Jordanian data to inform and bolster national policy initiatives focused on enhancing radiation protection and diagnostic uniformity in CT imaging.

 https://doi.org/10.2147/DHPS.S595721

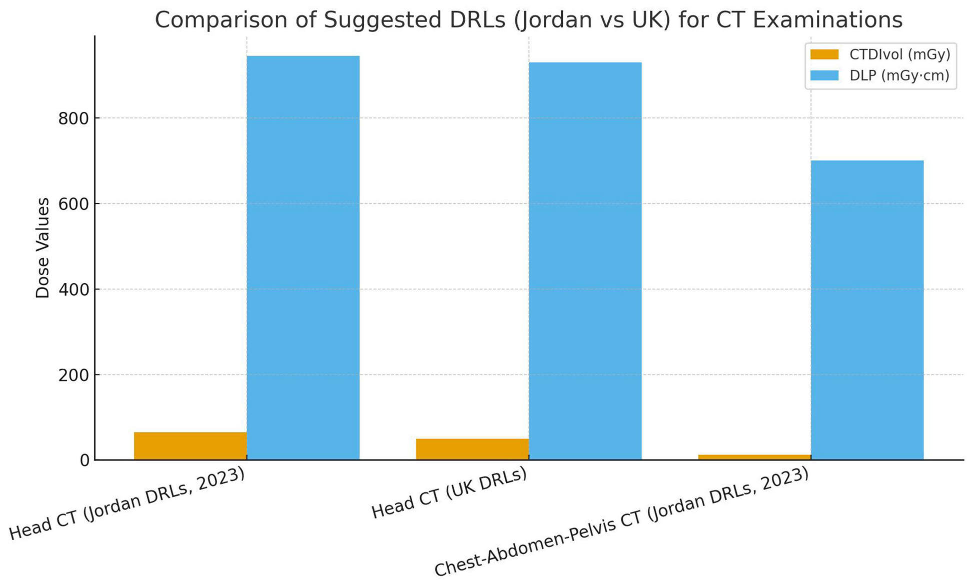

Figure 2 Comparison of suggested DRLs (Jordan vs UK) for CT examinations.

Challenges in Implementing DRLs in Low- and Middle-Income Countries (LMICs)

Despite the broad endorsement of DRLs for the optimization of radiation protection, their implementation is complex. The ICRP indicates that DRLs are valuable instruments for dose optimization, however they are often underutilized, particularly in LMICs.[70]

Human Resource Limitations in LMICs

Human resource constraints provide a substantial obstacle, notably a deficiency of qualified professionals, including medical physicists and radiologists. In numerous low- and middle-income countries, healthcare practitioners sometimes have excessive clinical responsibilities, resulting in minimal capacity for data collecting, analysis, or research dissemination.[120,121] Despite the availability of data, publication efforts may be obstructed by institutional limitations or elevated rejection rates in peer-reviewed journals. Consequently, 94% of low-income nations lack published DRL data, although probably possessing the most significant need due to their outdated imaging equipment and insufficient technical support.[102,122]

Table 2 Recommendation for Establishing DRLs in Jordan

Observation/Issue	Global Models/Inspirations	Recommended Actions for Jordan
High-quality dosage data exists but is scattered and unregulated	UK: national auditsJapan: tiered DRLsSaudi Arabia: academic initiatives	Establish national surveys or registries to gather representative dosage data
Reliance on specific facilities for data	—	Standardize CTDIvol and DLP reporting across institutions
Lack of regulation and coordinated methodology	ICRP: 75th percentile guideline	Formulate advisory DRLs in line with ICRP recommendations
Potential for improvement through continuous review	—	Evaluate DRLs every 3 to 5 years to reflect evolving practices
Need for stronger governance	—	Incorporate DRLs into regulatory or accrediting frameworks

Table 3 Key CT DRL Metrics and Methodological Considerations

Metric/ Concept	Definition	Unit	Typical Use in DRL Studies	Key Note
CTDIvol	Volume-weighted CT dose index denoting the scanner output averaged over the scanned volume.	mGy	Principal criterion for evaluating CT protocol results across scanners and locations.	Beneficial for standardization; nevertheless, it does not represent a patient-specific absorbed dose.
DLP	Dose-length product is determined by multiplying CTDIvol by the scan length.	mGy·cm	Principal metric of overall examination yield and one of the most often documented CT diagnostic reference level criteria.	Significantly affected by scan length; aids in detecting over-scanning.
SSDE	Size-adjusted dose estimation that modifies CTDIvol based on patient dimensions.	mGy	Essential when adjusting for patient size is critical, particularly in pediatric and adult body computed tomography.	Enhances patient relevance; nonetheless, it is not yet employed as consistently as CTDIvol and DLP in numerous DRL programs.
Standard-size adult patient	The reference adult patient is often characterized as weighing roughly 70 ± 15 kg.	Not applicable	Employed to standardize adult DRL surveys and enhance comparability across centers.	The selection criteria must be explicitly articulated in the techniques section.
Pediatric stratification	Classifying pediatric patients according to age, weight, or body size for dosage evaluation.	Not applicable	Crucial in the formulation of pediatric diagnostic reference levels due to the fast changes in body habitus with age.	Grouping based only on age may be less accurate than stratification based on weight or size.
DRL (75th percentile)	The investigation level is typically established at the third quartile of the dosage distribution for a certain assessment.	Same unit as reported dose metric	Commonly utilized national or regional benchmarks for optimization assessments.	This is an investigative threshold, not a regulatory or therapeutic dosage restriction.
Achievable dose (50th percentile)	A subordinate benchmark occasionally shown with the DRL to signify the standard performance of effectively optimized practice.	Same unit as reported dose metric	Utilized in certain programs to facilitate ongoing optimization beyond just compliance.	Beneficial when the manuscript addresses dual-threshold methodologies, including reference and achievable values.

Persistent Issues in High-Income Countries

Furthermore, issues continue to exist even in high-income nations. This encompasses varied interpretations of DRLs, resistance to modifications in clinical protocols, and the fallacy that DRLs denote dosage limitations instead of experimental thresholds. Such misunderstandings may compromise the optimization objective highlighted in ICRP Publication 135.[123]

Infrastructure and Regulatory Challenges

The World Health Organization (WHO) has noted the absence of regulatory agencies and quality assurance systems as significant barriers to the introduction of DRL in numerous countries. Establishing the requisite infrastructure—both physical and institutional—demands substantial investment as well as the formulation of educational programs, policy frameworks, and dependable health information systems. The lack of standardized electronic patient record systems hinders routine dose tracking and national data aggregation, both crucial for the creation of DRL.[70] See Table 3.

Conclusion

Although Jordan has generated useful local and multicenter CT dose data, the country still lacks a unified national framework for routine CT diagnostic reference levels. In the short term (within 12 months), a national working group should standardize CTDIvol and DLP reporting, define common adult CT examination categories, and conduct a baseline multicenter dose survey. In the mid-term (2–3 years), Jordan should establish provisional national DRLs, expand pediatric and indication-specific surveys, and implement regular audit and training programs in dose optimization. In the long term (3–5 years), DRLs should be integrated into accreditation, national quality assurance systems, and periodic revision cycles supported by coordinated regulatory oversight. These steps would improve radiation protection, promote protocol consistency, and strengthen safe CT practice in Jordan.

Data Sharing Statement

All data generated or analysed during this study are included in this published article.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

Acknowledgment

The authors express sincere gratitude to all collaborators in this endeavor, with special mention to the participants and medical staff, whose invaluable contributions greatly enriched this study.

Funding

This research received no external funding.

Disclosure

The authors declare no conflicts of interest in this work.

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