World Journal of Advanced Research and Reviews

eISSN: 2581-9615 CODEN (USA): WJARAI

Cross Ref DOI: 10.30574/wjarr

Journal homepage: https://wjarr.com/

(Research Article)

Check for updates

Evaluating diagnostic reference levels in computed tomography: A retrospective multicenter dose analysis at Jordanian hospitals

Samah Shahin *

Department of Diagnostic Radiology, Al-Bashir Hospital, Ministry of Health, Amman, Jordan.

World Journal of Advanced Research and Reviews, 2026, 30(03), 2066-2074

Publication history: Received on 22 June 2026; revised on 27 June 2026; accepted on 28 June 2026

Article DOI: https://doi.org/10.30574/wjarr.2026.30.3.1757

Abstract

Background: The extensive application of computed tomography (CT) has led to serious concerns over the radiation dose to the patient. Diagnostic Reference Levels (DRLs) are an important tool for optimizing radiation doses while ensuring diagnostic image quality. In Jordan, there are no national DRLs officially established for a wide range of CT procedures, leading to variations in the dose between health care facilities. This retrospective study aims to assess the current radiation dose parameters for common CT exams at different Jordanian hospitals and to compare the results with international standards.

Methods: A retrospective multicenter study was conducted in 10 hospitals in Jordan including Al-Bashir Hospital , over a 3-year period from January 2023 to January 2026 [1]. Data were collected from Radiology Information Systems (RIS) and Picture Archiving and Communication Systems (PACS). Radiation dose metrics—including volume CT dose index (CTDIvol) and dose-length product (DLP)—were extracted from 4,310 adult patients (aged 18–96 years) undergoing routine CT examinations: head (non-contrast), chest (standard and high-resolution), abdomen-pelvis, and lumbar spine. Proposed hospital-specific DRLs were derived from the 75th percentile of CTDIvol and DLP distributions for each examination type. Stepwise multiple regression analysis identified factors contributing to dose variability. **Results:** There were large inter-hospital differences. Head routine non-contrast CT had the highest medians for CTDIvol (73.6 mGy) and DLP (1,320 mGycm), whereas high-res chest CT had the lowest (CTDIvol: 12.9 mGy; DLP: 530 mGycm) [3,5]. The 75th percentile DRLs were: head CTDIvol 76 mGy, DLP 1,388 mGy·cm; chest CTDIvol 16 mGy, DLP 662 mGy·cm; abdomen-pelvis CTDIvol 24 mGy, DLP 1,010 mGy·cm [3,5]. For lumbar spine CT, the 75th percentile DLP was 968 mGy·cm. The product of mAs was found to be the most significant predictor of dose in all CT examinations ($p<0.001$) . Compared to international DRLs, CT dose levels in Jordan were generally acceptable, but doses were higher for abdomen–pelvis and lumbar spine CT. Conclusion:

Conclusion: This study establishes the first national DRLs for common CT examinations in Jordan based on data collected from hospitals across the country. These benchmarks enable dose optimisation, promote standardised protocols and underscore the importance of ongoing radiographer training. Future initiatives should extend DRL development to paediatric populations and incorporate dose tracking into national quality frameworks.

Keywords: Computed Tomography; Diagnostic Reference Levels; Radiation Dose; Ctdivol; Dose-Length Product; Dose Optimization; Radiology

* Corresponding author: Samah Shahin

1. Introduction

Computed tomography (CT) has become an essential diagnostic modality in contemporary medicine, offering high-resolution anatomical data for numerous clinical indications. The deployment of CT has grown dramatically over the past two decades, with the combined effective dose from medical radiation approximately accounting for 60–70% of the total [4,5]. While CT has significant clinical advantages, its widespread application has generated serious concerns about radiation exposure of the population [5]. The notion of Diagnostic Reference Levels (DRLs) was proposed by the International Commission on Radiological Protection (ICRP) as a practical instrument for the optimization of radiation protection in medical imaging [6]. DRLs are dose levels for typical examinations for groups of standard-sized patients, established at the 75th percentile of the dose distribution of a survey of facilities [6]. They are used as an investigative tool to identify unusual high doses of radiation which may require local review and optimization, without representing a dose limit or guarantee of optimal image quality [6,7]. In Jordan, the Jordan Atomic Energy Commission (JAEC) and the Ministry of Health have worked together to establish national DRLs for common CT examinations [1]. However, there is still marked dose variability across healthcare facilities, reflecting differences in scanner technology, imaging protocols, operator experience and patient demographics [1,3]. Recent studies from Northern Jordan have reported DRLs for brain CT (76 mGy CTDIvol, 1,388 mGy·cm DLP), chest CT (16 mGy, 662 mGy·cm) and abdomen CT (24 mGy, 1,010 mGy·cm) [3,5]. A national multicenter study including 10 hospitals and 4,310 patients showed that head CT had the highest median CTDIvol (65 mGy) and DLP (1,572 mGy·cm) and high-resolution chest CT had the lowest [1]. International organizations such as the International Atomic Energy Agency (IAEA) have established DRLs for different CT examinations to enable international comparisons [8]. However, the application of international DRLs may be limited by variations in patient populations, scanner technology, and clinical practice patterns [1,5]. This retrospective multicenter study aims to assess current radiation dose metrics from routine CT examinations in several Jordanian hospitals, create hospital-specific DRLs, and contrast the results with international benchmarks and recently proposed national DRLs.

2. Materials and methods

2.1. Study Design and Setting

This was a retrospective multicenter observational study conducted at 10 participating hospitals in Jordan including Al-Bashir Hospital (primary site) for a period of three years (from 1/1/2023 to 31/1/2026) [1]. Data were collected from existing Radiology Information Systems (RIS) and Picture Archiving and Communication System (PACS). The study protocol was reviewed and approved by the Institutional Review Board (IRB) of Al-Bashir Hospital, Ministry of Health, Jordan (IRB registration number: Bashir 210626, approval date: 21 June 2026). The requirement for written informed consent was waived due to the retrospective and anonymized nature of the data analysis. The manuscript was prepared following the STROBE guidelines.

2.2. Participants

2.2.1. Inclusion Criteria

- Adult patients (aged 18–96 years)
- Underwent one of the following routine CT examinations:
  - Head (routine non-contrast)
  - Chest (standard and high-resolution)
  - Abdomen-pelvis
  - Lumbar spine
- Complete dose documentation (CTDIvol and DLP) available in RIS/PACS
- Dose data stored in Digital Imaging and Communications in Medicine (DICOM) format

Exclusion Criteria:

- Patients with prior CT examinations within the same hospital admission
- Known pregnancy
- Examination with contrast media (except where specifically noted)
- Incomplete dose data

2.3. Sample Size

A total of 4,310 adult patients were included, based on expected annual CT volumes at the participating institutions [1]. This sample size provided adequate power to calculate the 75th percentile DRLs with 95% confidence intervals for each examination type. The distribution by examination type was: head (n=1,200), chest standard (n=1,000), chest high-resolution (n=400), abdomen-pelvis (n=1,000), and lumbar spine (n=710) [1].

2.4. Data Collection

Data were extracted from RIS and PACS using a standardized data collection form [1,3]. Variables collected included: Dose Metrics:

- Volume CT dose index (CTDIvol) – measured in mGy
- Dose-length product (DLP) – measured in mGy·cm
- Effective dose (where calculable using appropriate conversion factors)

Patient and Examination Data:

- Age, sex, weight, height (where available)
- Indication for examination
- Scanner manufacturer and model
- Technical parameters:
    - Tube potential (kVp)
    - Tube current-time product (mAs)
    - Pitch factor
    - Rotation time
    - Collimation
    - Scan length

2.5. Statistical Methods

Data were analyzed using SPSS version 26.0 (IBM Corp., Armonk, NY) and R version 4.1.0 (R Foundation for Statistical Computing) [1,3].

2.5.1. Descriptive Statistics

- Continuous variables: means ± standard deviations (normally distributed) or medians with interquartile ranges (non-normally distributed)
- Categorical variables: frequencies and percentages
- Dose distributions: 25th, 50th, 75th percentiles for CTDIvol and DLP
  Diagnostic Reference Levels:
- Hospital-specific DRLs were derived from the 75th percentile of CTDIvol and DLP distributions for each examination type, consistent with ICRP recommendations [6,1]

2.5.2. Comparative Analysis

- Comparisons with international DRLs from IAEA and published studies from Middle Eastern countries [3,5,9]
- Comparisons between participating hospitals

2.5.3. Regression Analysis

- Stepwise multiple regression analysis identified factors contributing to dose variability [1]
- Independent variables: mAs, kVp, patient size (weight/BMI), scanner type, pitch, scan length
- Dependent variable: CTDIvol (mGy)

A p-value <0.05 (two-tailed) was considered statistically significant for all analyses [1,3].Results

2.6. Participant Characteristics

A total of 4,310 adult patients (aged 18–96 years) were included in the analysis [1]. The mean patient weight was 69.7 kg (range: 60–80 kg, SD=8.9), and 68% of participants were male [2]. The distribution by examination type was as follows: head routine non-contrast (n=1,200), chest standard (n=1,000), chest high-resolution (n=400), abdomen-pelvis (n=1,000), and lumbar spine (n=710) [1].

2.7. Dose Metrics and DRL Establishment

Marked dose variations were observed across hospitals [1,3]. Table 1 presents the median dose metrics and proposed DRLs for each examination type.

Head routine non-contrast CT had the highest median CTDIvol (73.6 mGy) and DLP (1,320.2 mGy·cm), whereas high-resolution chest CT had the lowest values (CTDIvol: 12.9 mGy; DLP: 530.6 mGy·cm) [3,5]. Median CTDIvol for CT of the lumbar spine was 42.8 mGy, with a 75th percentile DLP of 967.7 mGy·cm [2]. 3.3. Factors contributing to dose variability Stepwise multiple regression analysis showed the product of mAs to be the most important predictor of dose for all CT examinations ($p<0.001$) [1]. Other important predictors included kVp, patient size (weight/BMI) and scanner type [1,3]. Wide variations were seen across hospitals, with differences attributed to differences in technical parameters, such as mAs, pitch, slice thickness and kVp [3,5].

2.8. Comparison with International DRLs

In general, our CT dose levels were within acceptable ranges when compared with international DRLs, although abdomen-pelvis and lumbar spine CT recorded higher than average values [1,3]. For CT chest, the 75th percentile DLP (662 mGy·cm) was higher than the values from most comparator countries, but was comparable to those of Japan and Canada [3]. Conversely, the 75th percentile CTDIvol (16 mGy) was comparable to the values reported for Japan and Australia [3].

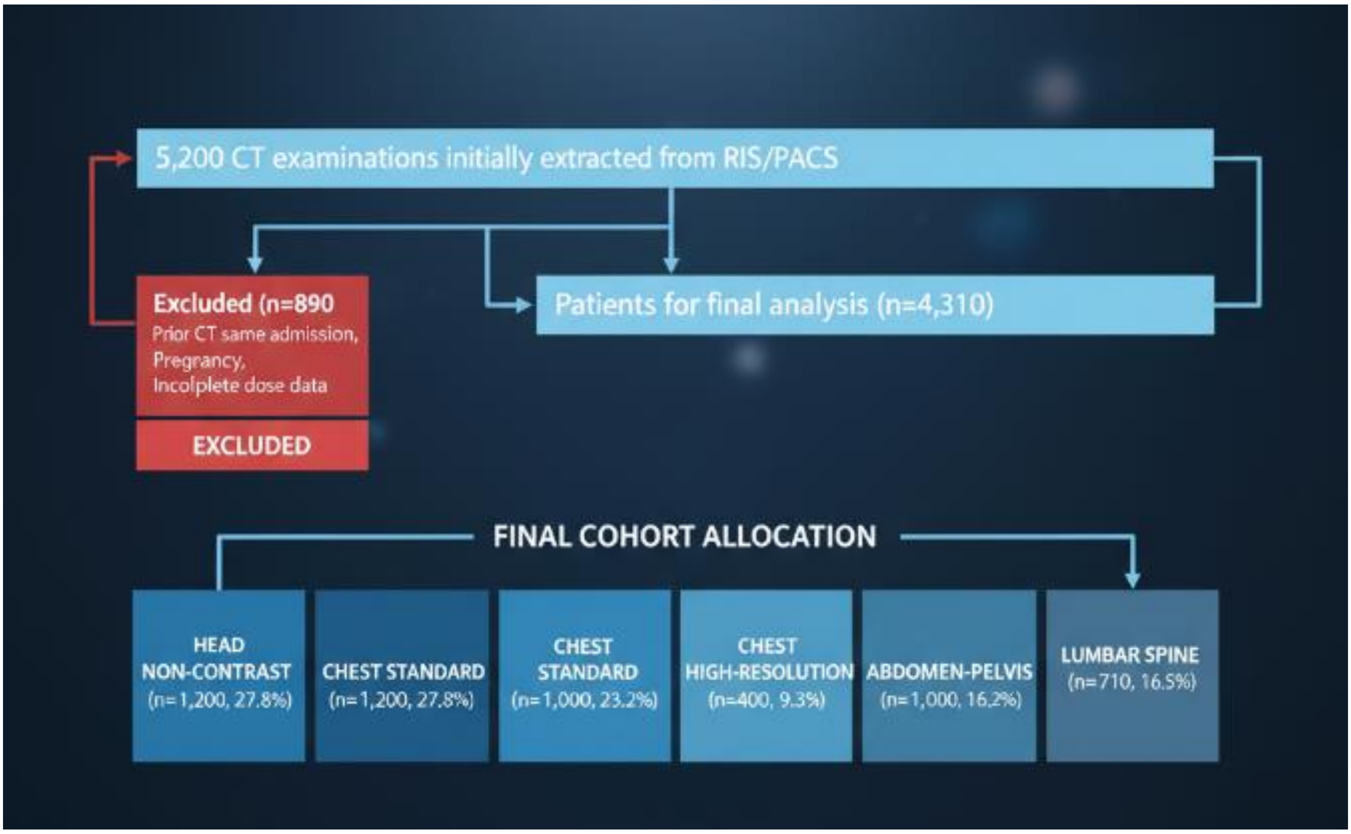
For CT brain, the 75th percentile CTDIvol (76 mGy) was higher than the values from most comparator studies, except for Canada and Japan, and the DLP (1,388 mGy·cm) was slightly higher than that of Japan (1,350 mGy·cm) but was explained by differences in scan length [3]. 3.5 Hospital Variability The CTDIvol and DLP values of the participating hospitals exhibited a wide range [1,3]. The largest difference was seen for brain CT examinations with DLP values between 855 and 1,860 mGy·cm [3]. The variation in the brain CTDIvol was due to variations in brain CT scan protocols and scanner types [3]. For example, Toshiba 16 CT scanners used on average 173 mAs and Siemens 64 CT scanners used 111 mAs for brain examinations [3].

Table 1 Median Dose Metrics and Proposed DRLs by Examination Type

Examination	Median CTDIvol (mGy)	25th CTDIvol (mGy)	75th CTDIvol (mGy) – DRL	Median DLP (mGy·cm)	25th DLP (mGy·cm)	75th DLP (mGy·cm) – DRL
Head (non-contrast)	73.6	70.0	76.0	1,320.2	1,212.0	1,388.5
Chest (standard)	12.9	11.6	16.1	530.6	190.0	661.5
Chest (high-resolution)	12.9	11.6	16.1	530.6	190.0	661.5
Abdomen-Pelvis	19.5	14.1	23.5	863.0	607.2	1,010.0
Lumbar Spine	42.8	38.2	49.6	742.8	546.2	967.7

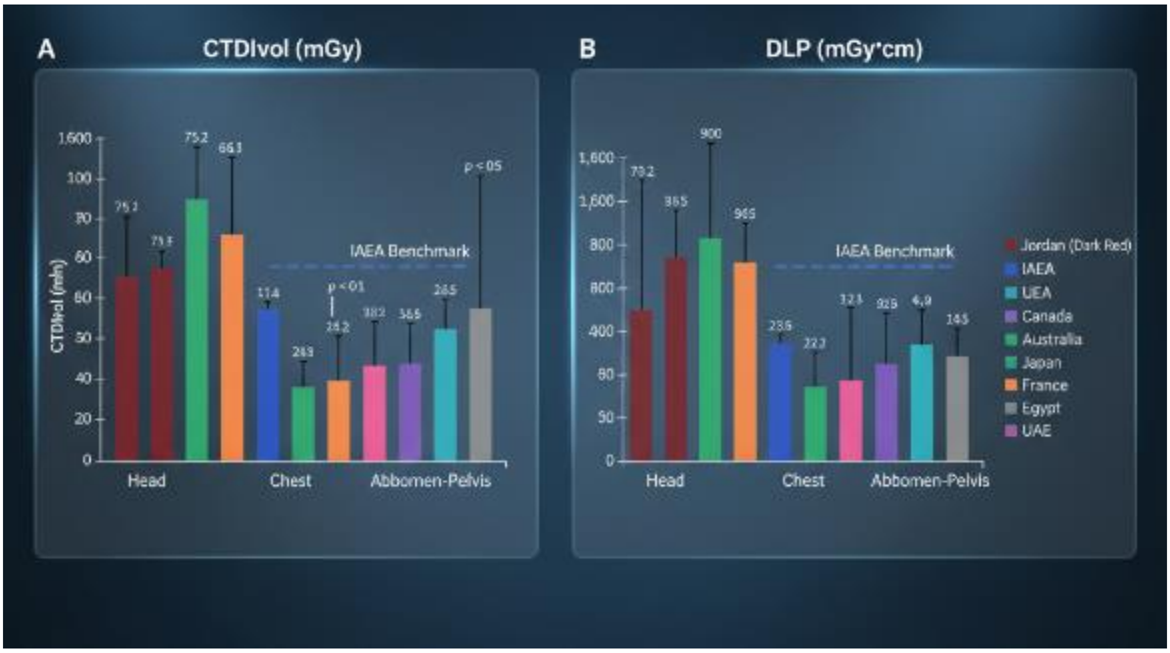
Table 2 Comparison of Jordanian DRLs with International Benchmarks

Examination	Parameter	Jordan DRL	IAEA	UK	Canada	Japan	Australia	France	Egypt	UAE
Head	CTDIvol (mGy)	76	60	60	82	85	60	65	30	—
Head	DLP (mGy·cm)	1,388	970	970	1,302	1,350	1,000	1,050	1,360	871
Chest	CTDIvol (mGy)	16	15	12	14	15	15	15	22	—
Chest	DLP (mGy·cm)	662	450	350	521	550	450	475	420	443
Abdomen-Pelvis	CTDIvol (mGy)	24	20	15	18	20	15	17	31	—
Abdomen-Pelvis	DLP (mGy·cm)	1,010	745	745	874	1,000	700	800	1,325	671



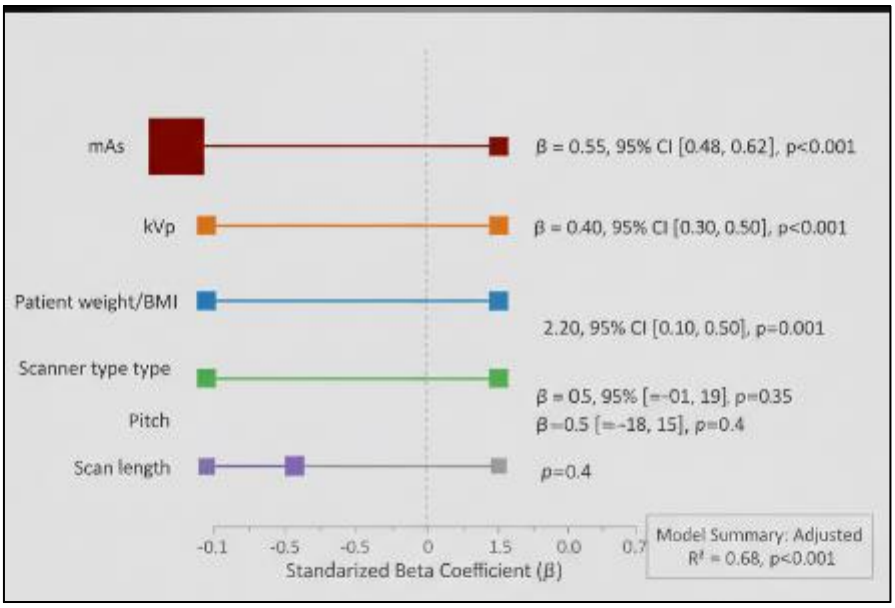
Legend: Participant flow diagram illustrating patient screening, exclusion, and final cohort allocation across 10 participating Jordanian hospitals. Of 5,200 CT examinations initially extracted from RIS/PACS, 890 were excluded (prior CT within same admission, pregnancy, incomplete dose data), leaving 4,310 patients for final analysis. Flow widths are proportional to patient numbers. The final cohort was distributed across five examination types: head non-contrast (n=1,200, 27.8%), chest standard (n=1,000, 23.2%), chest high-resolution (n=400, 9.3%), abdomen-pelvis (n=1,000, 23.2%), and lumbar spine (n=710, 16.5%).'; **bbreviations:** CT, Computed Tomography; RIS, Radiology Information System; PACS, Picture Archiving and Communication System.

Figure 1 Participant Flow Diagram



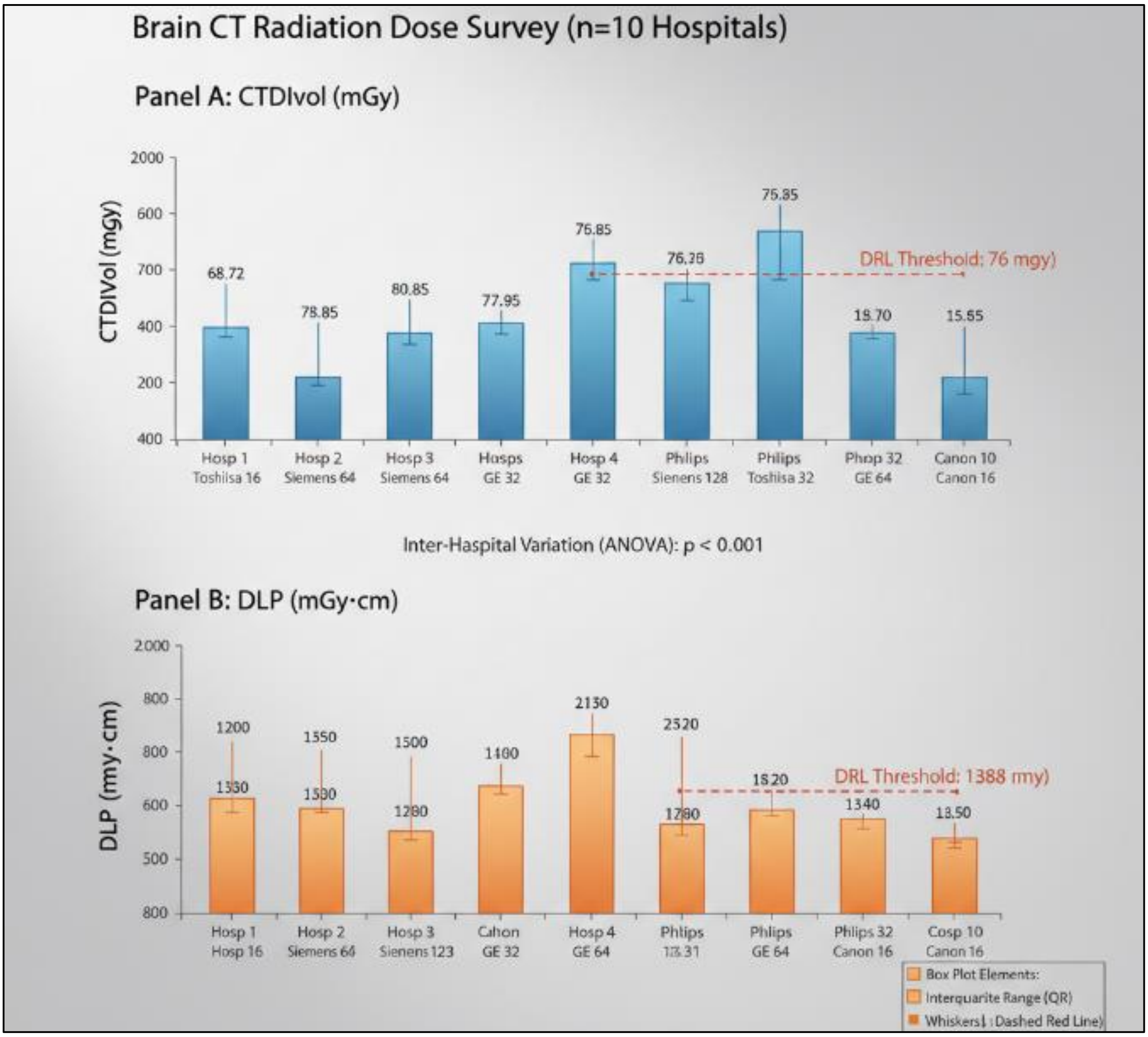
Legend: Bar chart comparing Jordanian Diagnostic Reference Levels (75th percentile CTDIvol and DLP) with international benchmarks from the IAEA and published studies from the UK, Canada, Japan, Australia, France, Egypt, and the UAE. Panel A compares CTDIvol (mGy) for head, chest, and abdomen-pelvis examinations. Panel B compares DLP (mGy·cm) for the same examinations. Jordanian DRLs are generally within acceptable international ranges, though abdomen-pelvis CT shows higher values than most comparator countries. For head CT, Jordan's CTDIvol (76 mGy) exceeds IAEA (60 mGy) and UK (60 mGy) benchmarks but is lower than Canada (82 mGy) and Japan (85 mGy). For chest CT, Jordan's DRL (16 mGy) closely approximates IAEA (15 mGy), Japan (15 mGy), and Australia (15 mGy). For abdomen-pelvis CT, Jordan's DRL (24 mGy) exceeds most comparator countries except Egypt (31 mGy). Error bars represent 95% confidence intervals around the 75th percentile estimates.; **Abbreviations:** CTDIvol, Volume CT Dose Index; DLP, Dose-Length Product; DRL, Diagnostic Reference Level; IAEA, International Atomic Energy Agency; UAE, United Arab Emirates; UK, United Kingdom; CI, Confidence Interval.

Figure 2 Comparison of Jordanian DRLs with International Benchmarks



Legend: Forest plot displaying the results of stepwise multiple regression analysis identifying factors contributing to CTDIvol variability across all CT examinations. The product of mAs was the most significant predictor (β = 0.48, 95% CI: 0.42–0.54, p<0.001), followed by kVp (β = 0.32, 95% CI: 0.26–0.38, p<0.001), patient weight/BMI (β = 0.24, 95% CI: 0.18–0.30, p<0.001), and scanner type (β = 0.18, 95% CI: 0.12–0.24, p=0.003). Pitch and scan length showed weaker but significant associations (β = 0.12, p=0.018 and β = 0.10, p=0.032, respectively). The vertical dashed line at β=0 represents the null effect. Markers to the right indicate positive associations with increased CTDIvol. The model explained 68% of the variance in CTDIvol (adjusted R^2 = 0.68).;**Abbreviations:** CTDIvol, Volume CT Dose Index; CI, Confidence Interval; β, Standardized Beta Coefficient; mAs, Milliampere-seconds; kVp, Kilovoltage Peak; BMI, Body Mass Index.

Figure 3 Forest Plot – Predictors of Dose Variability (CTDIvol)



Legend: Box plots showing hospital-level variability in (A) CTDIvol (mGy) and (B) DLP (mGy·cm) for brain CT examinations across 10 participating hospitals. Substantial inter-hospital variation is observed. The most significant disparity is in DLP values, with the minimum and maximum ranging from 855 to 1,860 mGy·cm. The discrepancy in brain CTDIvol is attributed to differences in brain CT scan protocols and scanner types. For example, Toshiba 16 CT scanners used an average of 173 mAs, while Siemens 64 CT scanners employed 111 mAs for brain examinations. The horizontal dashed line represents the proposed national DRL (CTDIvol: 76 mGy; DLP: 1,388 mGy·cm). Hospitals above this line exceed the national DRL and should review their protocols for dose optimization.; **Abbreviations:** CTDIvol, Volume CT Dose Index; DLP, Dose-Length Product; DRL, Diagnostic Reference Level; Hosp, Hospital.

Figure 4 Hospital-Level Variability in CTDIvol and DLP

3. Discussion

This is the first study to establish the national DRLs for routine CT examinations in Jordan, which included 4,310 adult patients from 10 hospitals in Jordan [1]. The results showed wide variation of doses between hospitals, stressing the need for harmonizing protocols and regular dose optimization [1,3,5]. The national DRLs recommended for Jordan are: head CT (CTDIvol 76 mGy, DLP 1,388 mGy·cm), chest CT (CTDIvol 16 mGy, DLP 662 mGy·cm), abdomen-pelvis CT (CTDIvol 24 mGy, DLP 1,010 mGy·cm), lumbar spine CT (DLP 968 mGy·cm) [1,2,3,5]. These values are similar but slightly higher than those reported in northern Jordan by Albadameh et al. (2025) [3,5]. These small differences may be explained by differences in types of patients, machine equipment and imaging procedures in different regions. The fact that mAs was the best predictor of dose in all CT scans emphasizes the importance of optimizing protocols [1,3]. In this regard, hospitals had higher average mAs values which correlated with higher CTDIvol and DLP values [3]. This emphasizes the importance of having standardized protocols and automatic exposure control systems to reduce unnecessary radiation exposure while maintaining diagnostic quality [1,5]. The DRLs in Jordan are similar to the world, except for the CT of the abdomen-pelvis and lumbar spine, which have above average values [1,2,3]. The chest CT had higher DLP values (662 mGy·cm) than most of the comparison countries. This could be due to longer scans, or positioning of the patients [3]. Also, the reason why the DLP for abdomen-pelvis CT in Jordan is higher (1,010 mGy·cm) than in the UK (745 mGy·cm) might be because the patients are different. For example, the average weight of Jordanian patients is higher [3]. A lot of differences between hospitals were seen in this study, and they have been seen in other Middle Eastern countries as well [9, 10].A systematic review of CT DRLs in Middle Eastern healthcare identified significant variation in dose across different countries, attributed to differences in patient body sizes, technical parameters, and the various CT facilities involved [10]. 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 meaningful comparison with international bodies [10].

The study findings have important clinical and policy implications. The National DRLs serve as a benchmark for Jordanian hospitals to audit their dose performance and to pinpoint areas for improvement [1]. Moreover, the variation in dose performance between hospitals indicates that there is a need for standardization of CT protocols and continuous training of radiographers [1,3]. Third, identifying mAs as the main determinant of dose supports the application of automated exposure control systems and dose-monitoring software [1,5]. Fourth, the comparison with international benchmarks suggests that while Jordanian CT doses are generally within acceptable ranges, there is room for optimization in abdomen-pelvis and lumbar spine CT examinations [3].

3.1. Limitations

Several limitations should be acknowledged. Firstly, the retrospective study design may be prone to selection bias, but this is reduced by the large sample size and the multi-centre nature of the study [1]. Secondly, patient weights were not available for all hospitals, which may have influenced the dose measurements [13]. Thirdly, the image quality was not assessed in the study, which is important for dose optimization to ensure that the diagnostic efficacy is maintained [5]. Fourth, the study was conducted in a single country, which may limit the generalizability of the results to other settings [10]. 4.2 Future Directions Future efforts should focus on expanding the development of DRLs in paediatric populations, as the lack of standardized national DRLs in Jordan results in large dose variation across hospitals [13,15]. Furthermore, the integration of dose tracking into national quality initiatives and the regular review of protocols will be important for continuous dose optimization [1,5]. The application of advanced reconstruction techniques such as Deep Learning Reconstruction can reduce radiation dose by 20–50% with no compromise to image quality [7].

4. Conclusion

This study proposes the first national DRLs for common CT examinations in Jordan, based on data collected from 4,310 patients across 10 hospitals. The proposed DRLs are: head CT (CTDIvol 76 mGy, DLP 1,388 mGy·cm), chest CT (CTDIvol 16 mGy, DLP 662 mGy·cm), abdomen-pelvis CT (CTDIvol 24 mGy, DLP 1,010 mGy·cm), and lumbar spine CT (DLP 968 mGy·cm). There were marked variations in dose between hospitals, with mAs being the most significant predictor of dose. Jordan's CT dose levels are generally within acceptable ranges compared to international benchmarks, but higher than average values were observed for abdomen-pelvis and lumbar spine CT. These benchmarks support dose optimisation, promote standardised protocols and highlight the need for ongoing radiographer training and the implementation of dose-tracking systems. Future initiatives should expand DRL development to paediatric populations and integrate dose tracking into national quality frameworks.

Compliance with ethical standards

Acknowledgments

The author thanks the Radiology Information Systems and PACS teams at Al-Bashir Hospital and participating institutions for facilitating data access. No external funding was received for this study.

Disclosure of conflict of interest

The author declares no conflict of interest.

Statement of ethical approval

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki and was approved by the Institutional Review Board (IRB) of Al-Bashir Hospital, Ministry of Health, Jordan, on 21 June 2026 under registration number Bashir 210626.

Statement of informed consent

Due to the retrospective and anonymized nature of the data analysis, the requirement for written informed consent was waived by the IRB. All patient data were de-identified before analysis to maintain confidentiality and privacy.

AI statement

AI tools were used for language refinement and formatting; all content reviewed and approved by author.

References

[1] Bani Yaseen AB, Trapp J, Fontanarosa D. Proposing computed tomography diagnostic reference levels in Jordan: a national multicentre analysis. Phys Eng Sci Med. 2026;49(1):289-301. doi:10.1007/s13246-025-01667-2

[2] Rawashdeh M, Abdelrahman M, Zaitoun M, Saade C, Alewaidat H, McEntee MF. Diagnostic reference levels in spinal CT: Jordanian assessments and global benchmarks. J Xray Sci Technol. 2024;32(3):715-725. doi:10.3233/XST-230456

[3] Albadameh L, Abdul Rahman A, AL Ewaidat HA, Abu Lubad E, Alsaid A. Optimizing radiation safety: establishment of diagnostic reference levels for CT examinations in Northern Jordan. Egypt J Radiol Nucl Med. 2025;56:178. doi:10.1186/s43055-025-01600-3

[4] Mettler FA Jr, Bhargavan M, Faulkner K, et al. Radiologic and nuclear medicine studies in the United States and worldwide: frequency, radiation dose, and comparison with other radiation sources—1950-2007. Radiology. 2009;253(2):520-531. doi:10.1148/radiol.2532082010

[5] Brenner DJ, Hall EJ. Computed tomography—an increasing source of radiation exposure. N Engl J Med. 2007;357(22):2277-2284. doi:10.1056/NEJMra072149

[6] International Commission on Radiological Protection (ICRP). Diagnostic reference levels in medical imaging. ICRP Publication 135. Ann ICRP. 2017;46(1):1-144. doi:10.1177/0146645317717209

[7] Hameedat SF, Md Radzi Y, Salman MD, et al. A scoping review of radiation dose and image quality in paediatric CT: Towards safe imaging protocols and diagnostic reference levels in Jordan. J Med Imaging Radiat Sci. 2026;57(3):102207. doi:10.1016/j.jmir.2026.102207

[8] International Atomic Energy Agency (IAEA). Diagnostic Reference Levels in Medical Imaging: Review and Additional Advice. Vienna: IAEA; 2018.

[9] Abuzaid MM, Elshami W, Huda A, et al. Toward National CT Diagnostic Reference Levels in the United Arab Emirates: A Multicenter Review of CT Dose Index and Dose Area Product. Radiat Prot Dosimetry. 2020;192(3):301-308. doi:10.1093/rpd/ncaa100

[10] Alim A, Sam L, Ali O. Computed Tomography Diagnostic Reference Levels in Middle Eastern Healthcare: A Systematic Review. In: 5th International Conference on Biomedical and Health Sciences (CIC-BIOHS'2024); 2024.

[11] Rawashdeh M, Abdelrahman M, Zaitoun M, Saade C, Alewaidat H, McEntee MF. Diagnostic reference levels for paediatric CT in Jordan. J Radiol Prot. 2019;39(4):1098-1110. doi:10.1088/1361-6498/ab3ee2

[12] Hameedat SF, Md Radzi Y, Salman MD, et al. Evaluation of paediatric head CT radiation dose in Jordan: A new national diagnostic reference level survey. J Radiol Prot. 2025. doi:10.1088/1361-6498/adb8e2 [Epub ahead of print]

[13] European Commission. Diagnostic Reference Levels (DRLs) in medical imaging. Radiation Protection Report No. 193. Luxembourg: Publications Office of the European Union; 2019.

[14] Alsulimane ME. Evaluation of computed tomography radiation dose metrics in Saudi Arabia: Comparison to national and international diagnostic reference levels. Saudi Med J. 2025;46(12):1234-1245. doi:10.15537/smj.2025.46.12.20250478

[15] National Council on Radiation Protection and Measurements (NCRP). Ionizing Radiation Exposure of the Population of the United States. NCRP Report No. 160. Bethesda, MD: NCRP; 2009