Tuijin Jishu/Journal of Propulsion Technology
ISSN: 1001-4055
Vol. 46 No. 2 (2025)

Assessing the Accuracy and Efficiency of Dose Management Systems in Establishing Local Diagnostic Reference Levels for Adult CT Examinations

[1]M. ALBastaki, [2]Z. Embong, [3]NK. ALMazrouei, [1]A. ALShaali,[1]F. Thajudeen, K A Noor[4]

[1]Zayed Military Hospital, Diagnostic Imaging Department, Sharjah, UAE,

[2]Department of Physics and Chemistry, Faculty of Applied Sciences and Technology (FAST), University Tun Hussien Onn Malaysia (UTHM), MALAYSIA,

[3]Dubai Health, Dubai Hospital, Medical Physics Department,

[4] Dubai Health, Dubai Hospital, Radiology Department

Corresponding author: *Maryam Abdulla Abdulrahman ALBastaki, Medical Physicist, Ration Protection Officer, Zayed Military Hospital, Diagnostic Imaging Department, Sharjah, UAE,*

Abstract: **-** Background: Computed tomography (CT) contributes significantly to radiation exposure due to its high dose levels. Diagnostic Reference Levels (DRLs) are essential tools for optimizing clinical procedures and minimizing excessive exposure. This study compares manual data collection with an automated Dose Management System (DMS) to determine local diagnostic reference levels (LDRLs) for common adult CT exams at Sharjah Zayed Military Hospital.

Methods: A comparative study was conducted using two data collection methods: (1) manual extraction of radiation dose data from CT scanners and DICOM headers, and (2) an automated DMS. The study evaluated sample size, data collection efficiency, and statistical agreement in CT dose index-volume (CTDIvol) and dose length product (DLP) values between the two methods.

Results: The automated system significantly increased the sample size (479 vs. 80) and reduced data collection time by 75%. Statistical analysis demonstrated strong agreement between both methods, with percentage differences in median CTDIvol and DLP values ranging from –0.36% to 24.7% across CT protocols. Additionally, the DMS improved data standardization.

Conclusion: DMS provides a more efficient and scalable approach to establishing LDRLs, enhancing data collection, standardization, and radiation dose monitoring in CT imaging. Integrating DMS into clinical practice supports radiation dose optimization, improves data accuracy, and enhances patient safety and quality assurance.

Keywords*: Computed tomography, diagnostic reference levels (DRLs), dose length product, CT dose index-volume, Dose Management System.*

1. Introduction

Computed tomography (CT) is associated with high radiation exposure in diagnostic imaging. Adhering to radiation protection principles, justification, optimization, and limitation are essential for safe use.1–4 The International Commission on Radiological Protection (ICRP) highlights optimization as a key to ensuring radiological protection, particularly in diagnostic imaging.[5–9] The ICRP introduced diagnostic reference levels (DRLs) in 1996 to optimize ionizing radiation exposure in medical imaging, including CT scans. DRLs assess whether amount of radiation doses for radiology procedures is within expected ranges.10–15 Regulation 24

(Version 1) of the Federal Authority for Nuclear Regulation (FANR) in the UAE defines DRLs as benchmarks for evaluating whether the patient dose is exceptionally high or low under standard conditions.[16]

CT DRLs are determined using CT dose index-volume ($CTDI_{vol}$), which measures radiation absorbed per gantry rotation (mGy), and dose length product (DLP), which quantifies total exposure based on scan length (mGy.cm)[5,8,17–19] The ICRP acknowledges the digital imaging and communication in medicine (DICOM) committee's efforts to engage clinical specialists, medical physicists, and radiographers in dose management. Integrating imaging capability with radiation dose monitoring is crucial for standardized quality control.[18,20]

EuroSafe Imaging formed a working group in 2019 to integrate dose management into practice and promote the dose management system (DMS) for DRL development at local, national, and European levels. Designed for radiographers, medical physicists, and other professionals, the DMS ensures compliance with radiation safety regulations by collecting dosimetric data, identifying excessive exposures, and optimizing radiation doses. These systems automate dose tracking, reporting, and alerts while supporting comparative analysis to identify trends and enhance radiation safety efficiency.[21–24] Many countries mandate radiation exposure recording. Before electronic tools like radiology information system (RIS), picture archiving and communication system (PACS), and dose monitoring software, data were kept as hardcopies, customized for each modality's dose attributes.[18,25] This study assesses the accuracy and agreement between the DICOM header and PACS in recording $CTDI_{vol}$ and DLP compared to the DoseWatch system and evaluates its effectiveness for local dose tracking.

2. Methods

Upon ethics approval, this study analyzed CT exams at Zayed Military Hospital (March 2023–March 2024), comparing manual data collection with DoseWatch, an automated dose monitoring system. Data was extracted from DICOM displays (Figure 1) and PACS, with DoseWatch automating dose tracking for retrospective analysis. The study calculated local diagnostic reference levels (LDRLs) and compared both methods. A total of 559 patients were included, with 80 manual and 479 automated data. The exams covered brain, chest, and kidney ureter bladder (KUB) scans, with data transferred from PACS to the DoseWatch servers. The patients were aged 17+ years and more, and data acquisition involved age, gender, kilovoltage (kV), milliampere (mA), scan time, scan length, rotation time, pitch factor, field of view, CTDIvol, and DLP.

The Optima 660 128-Slice System (GE, 2016) was used, with standardized protocols: brain exams used non-contrast helical acquisition (5-mm slice thickness), localized chest exams followed a low-dose technique (120 kV, automatic tube current modulation), and KUB exams had 5-mm slices with 1.4 pitch for optimized scan time and image quality.

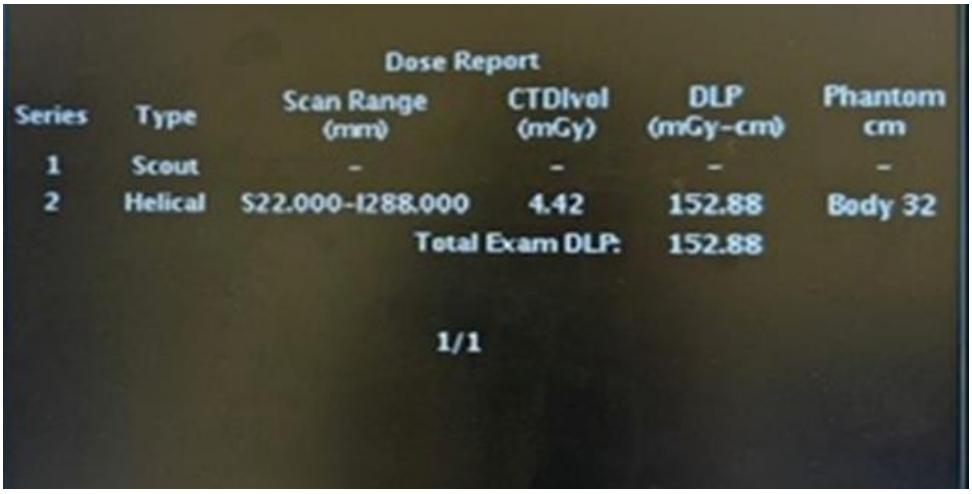

Figure 1 : Dose report displayed $CTDI_{vol}$ (mGy) and DLP (mGy.cm) from the DICOM header in the CT scanner console

A. Calculating DRL using the Data Collection Method

Data from 20 to 30 adult patients (> 16 years, 75 ± 10 kg) were selected for common CT exams, including brain, chest, and KUB (Table 1). The scanner protocol enabled efficient retrieval of scan parameters, including mAs, kV, pitch, rotation time, and slice thickness (Table 1). CTDIvol and DLP values were recorded from the scanner console for DRL. The minimum, maximum, and 25th percentile median values were calculated for CTDIvol and DLP across all exams. Table 2 presents the mean and standard deviation for patient characteristics, while LDRLs were derived from the median of DRL distributions for the hospital.

Table 1: Manually collected patient data and exposure parameters:

Exposure parameters	**CT Brain/Head**	**CT Chest (Localized)**	**CT KUB**
Patient Sex	28 M, 2 F	19 M, 1 F	29 M,1 F
Patient Age (year)	22-71	17–66	19-65
Patient weight (kg)	65–85	65–85	65-85
Patient size (Height -cm)	158-190	159–183	157-183
Tube voltage (kV)	140	120	120
Milliampere (mA)	125	100	120
Slice thickness (mm)	5	5	5
Exposure time per rotation (s/rot)	0.7	0.5	0.6
Pitch	0.5	0.9-1	1.4
Scan Length (mm)	7.9 ± 3	13.9 ± 2.5	37 ± 7.5

Table 2: Mean and standard deviation of patient's characteristics through three examinations:

Patient Characteristics (Manual Collection)									
Statistical	Brain			Chest			KUB		
	Age	Height (cm)	Weight (kg)	Age	Height (cm)	Weight (kg)	Age	Height (cm)	Weight (kg)
Mean	39	170	76	32	171	78.7	36	171	77.6
Standard deviation	16.9	7.4	6.7	13.2	5.8	6.2	11.6	6.3	5.3

B. Calculating DRL using the DMS (DoseWatch)

The DoseWatch is an automated dose management tool that collects and analyzes patient radiation exposure data from medical imaging. CT data were filtered by protocol, patient description, cumulative dose, and high radiation dose studies. Brain, localized chest, and KUB exam data over 12 months were exported into Excel. Only adult patients were included to ensure data quality and duplicate or incomplete exams were removed. Protocol names in the DoseWatch were verified, with misclassified studies corrected or excluded if uncertain. The statistical analysis determined minimum, maximum, and median (50th percentile) values for patient characteristics, exposure parameters, and dose metrics (CTDIvol and DLP). Table 3 presents the mean and standard deviation for patient characteristics, while Table 4 summarizes the average exposure parameters and patient data.

Table 3: Mean and standard deviation of patients' characteristics using the DoseWatch over three examinations:

Patient Characteristics (Automatic Collection)									
Statistical	Brain			Chest			KUB		
	Age	Height (cm)	Weight (kg)	Age	Height (cm)	Weight (kg)	Age	Height (cm)	Weight (kg)
Mean	37	170	81	31	167	77.7	37	172.9	83
Standard deviation	17.2	7.7	17.8	14.6	6.7	13	11.2	6.07	18.2

Table 4: Patient characteristics and exposure parameters exported from DoseWatch

Local study description	**CT Brain/Head**	**CT Chest (Localized)**	**CT KUB**
Patient sex	211 M, 14 F	114 M, 3 F	132 M, 5 F
Patient weight (kg)	46-135	55-114	45-138
Patient Age (year)	16-90	17-75	17-77
Patient size (Height- cm)	150-192	154-181	175-188
Slice thickness (mm)	5	5	5
Tube voltage (kV)	140	120	120
Milliampere (mA)	125	100	120
Pitch factor	0.53	0.89	1.38
Exposure time per rotation (s/rot)	0.7	0.50	0.60
Scan Length (cm)	18±2.3	31.7±3.17	45.8±9.5

3. Results

Data from 80 patients were gathered manually, while the software obtained 479 data. Both data sets were analyzed for the brain, chest, and KUB CT exams by comparing median values to assess accuracy and reliability. Similar results were observed in the CTDIvol and DLP values for the LDRL for the brain, chest, and KUB exams in both methods. The median CTDIvol (mGy) values for the brain, chest, and KUB are 40.26, 4.42, and 5.43, as shown in Table 5 for the manual collection. Meanwhile, for the automatic collection, the median CTDIvol (mGy) values for the brain, chest, and KUB are 40.60, 4.42, and 4.70. Moreover, a similar finding was observed for the median values of DLP (mGy.cm). Table 6 displays the statistical analysis for manual collection data, where the median values for DLP (mGy.cm) for brain, chest, and KUB are 727.38, 78.87, and 247. The automatic collection of the median values of DLP (mGy.cm) values for the brain, chest, and KUB are 729.93, 88.73, and 217.47.

Table 5: LDRL using manual collection based on $CTDI_{vol}$ (mGy)

LDRL Manual Collection ($CTDI_{vol}$ mGy)			
Protocol			
Statistical	Brain	Chest	KUB
Average	41.4	4.5	5.25
Standard deviation	2.4	0.4	1.5

Minimum	40.26	3.96	3.42
Maximum	50.33	5.9	8.28
Median	40.26	4.42	5.43

Table 6: LDRL using manual collection based on DLP (mGy.cm)

LDRL Manual Collection (DLP mGy.cm)			
Protocol			
Statistical	Brain	Chest	KUB
Average	763.5	79.2	249.9
Standard deviation	66.3	10.96	73.5
Minimum	633.53	51.75	147.1
Maximum	899.95	99	385.5
Median	727.38	78.87	247

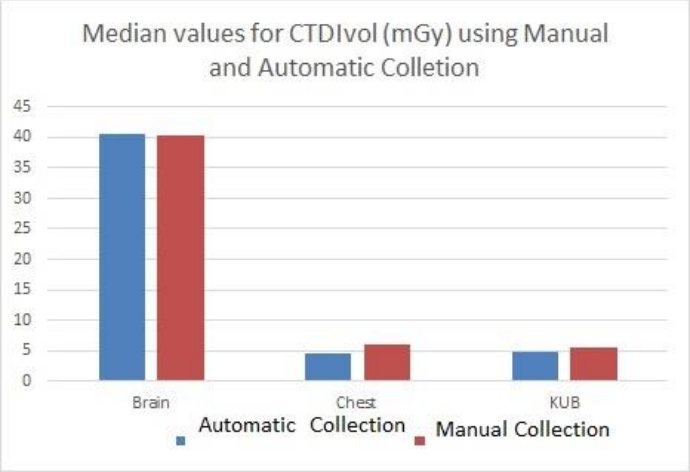

Figure 2: Median values based on $CTDI_{vol}$ (mGy) for manual and automatic data collection

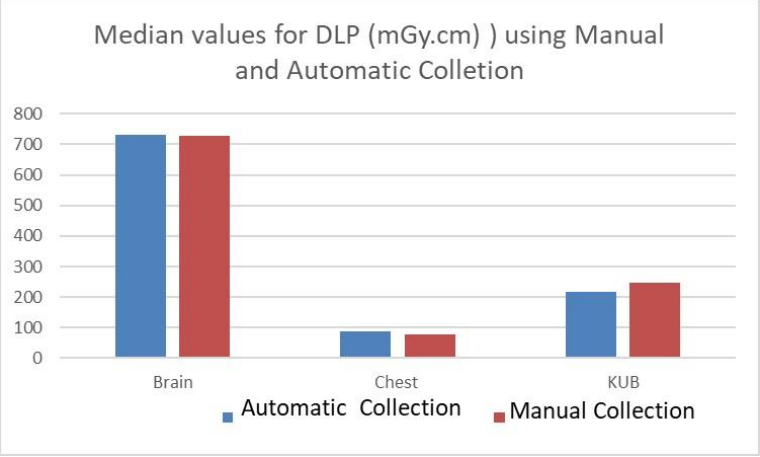

Figure 3: Median values based on DLP (mGy.cm) for manual and automatic data collection

Compassion between method one and the DMS (DoseWatch)

The most significant advantage of the dose management software is the ability to collect data from many patients, enhancing the accuracy of collected data, where the samples are not weight-restricted according to ICRP recommendations.27 Table 7 presents the patient distribution across both methods, i.e., manual and automated data collection, with method two (automated data collection) yielding a significantly larger sample size than method one (manual data collection). Table 8 compares the percentage difference in median CTDIvol and DLP values between the two methods.

Table 7: Numbers of patients collected from CT studies for both methods

CT Protocol	Manual Collection	Automatic Collection
brain	30	225
Chest	20	117
KUB	30	137

Table 8: Difference between manual and automatic data collection

	Automatic Collection		Manual Collection			
Statistical Analysis	Median		Median		% Difference $CTDI_{vol}$	% Difference DLP
Dose Quantities	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)	DLP (mGy.cm)	$CTDI_{vol}$ (mGy)		
Brain	729.93	40.6	727.3	40.26	-0.36%	-0.84%
Chest	88.73	4.42	78.87	5.87	-12.50%	24.70%
KUB	217.47	4.7	247	5.43	11.96%	13.44%

4. Discussion

The automated method collected data more rapidly than the manual (Table 7). CTDIvol and DLP of the key radiation dose metrics showed minimal differences in brain exams (–0.36% CTDIvol and –0.84% DLP) but more significant discrepancies in KUB and chest exams due to patient size variations affecting scan length and DLP values (Table 8). Manual scan lengths for chest and KUB exams were 13.9 ± 2.5 and 37 ± 7.5 cm (Table 1), while automated results recorded 31.7 ± 3.17 and 45.8 ± 9.5 cm (Table 4). These differences highlight the need for standardized CT protocols for accurate DRLs.

A challenge in automated data collection is inconsistent protocol names, affecting dose calculations. Manual collection, though accurate, is time-consuming and prone to errors like illegible entries and mismatched dose parameters. Training is crucial for optimizing software use and dose tracking. Despite limitations, automated DMS enhances efficiency, data collection, and monitoring, supporting DRL standardization and quality improvement. Future research could focus on protocol standardization and AI integration for data cleaning and protocol to improve accuracy and efficiency.

5. Conclusion

This study compared manual data collection and DoseWatch to establish LDRLs at Zayed Military Hospital. Results confirm the efficiency of automated DMS, showing close agreement in brain CT exams but discrepancies in chest and KUB scans due to patient size variability. These findings emphasize the need for standardized protocols in dose optimization. DoseWatch improves data accuracy, efficiency, and monitoring, leading to more reliable LDRLs. Future improvements should focus on protocol standardization, AI integration, and patient-

specific dose adjustments. While both methods establish LDRLs, automated DMS offers a more scalable and effective solution, enhancing dose optimization and patient safety.

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