RESEARCH ARTICLE

Establishment of institutional diagnostic reference level for Computed Tomography dose on 160 slicer Computed Tomography scan at Lady Reading Hospital Peshawar

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Abstract

Objective: To set institutional diagnostic reference level for computed tomography of multiple anatomical regions using dose length product as dosimeter parameter and to compare results with international diagnostic reference level.

Method: The retrospective study was conducted at the Radiology Unit of Lady Reading Hospital, Peshawar, Pakistan, and comprised dose data of patients who underwent computed tomography from June 1 to August 31, 2018. The mean, 25th, 50th and 75th percentile of dose distribution of common computed tomography examinations was calculated and compared with other established diagnostic reference levels. Data was analysed using SPSS 20.

Results: Of the 1001 scans, 143(14.2%) related to brain, 275(27.5%) abdomen-pelvis, 133(13.3%) kidney-ureter-bladder, 186(18.58%) thorax, 85(8.49%) triphasic, 126(12.58%) musculoskeletal, and 53(5.29%) cardiac. Institutional diagnostic reference levels for the computed tomography unit was established as 50th percentile of dose length product for different regions brain 339, abdomen-pelvis 298, thorax 165, kidney-ureter-bladder 302, triphasic 633, musculoskeletal 366 and cardiac 403. Both 50th and 75th percentile values of dose length product for each individual body region was lower than international Diagnostic reference levels.

Conclusion: The diagnostic reference level will be used in routine computed tomography practice at the institution, and will act as the baseline for developing the national diagnostic reference levels.

Keywords: CT dose, Dose-length product, Diagnostic reference level, Institutional DRL, National DRL.

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Introduction

Computed tomography (CT) is a powerful clinical tool for the diagnosis and management of patients. Due to its ability to provide high-quality three-dimensional (3D) images and ongoing technological advances, like CT angiography CTA) and colonography (CTC), it adds significant benefits to medical management by ensuring faster and more accurate diagnosis. Despite these improvements, unfortunately, the dose delivered to patients has increased, which in turn causes concerns about cancers induced by radiation, such as leukaemia and brain tumours in children and adolescences.[1,2]

It is important to adhere to the principles of radiation protection (justification, optimisation, and minimisation) so that the risk to patients does not exceed the benefits of the technology.[3] It is necessary to apply specific scanning protocols which should be used according to the patient's age and size, imaging area, and clinical indications to ensure that each patient's dose is in line with the As Low As Reasonably Achievable (ALARA) principle.[4]

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Because of medical procedures, citizens of developed countries were exposed to seven times more ionizing radiation in 2006 than in the early 1980s with CT scans contributing 50% of the total radiation from medical imaging procedures in the United States.[5] There is 20% reduction in CT dose with use of newer dosimetry methods, and the collective medical dose radiation to population has decreased from 2.9 millisievert (mSv) in 2006 to 2.3 mSv in 2016.[6]

To cope with growing medical exposure, the International Atomic Energy Agency (IAEA)[7] in 2006 and the International Radiological Protection Commission (ICRP) in 2007[3] recommended the establishment of a diagnostic reference level (DRL) as a tool to curb the increasing medical exposure and optimisation of the radiation dose delivered to patients during diagnostic procedures while meeting clinical goals. The establishment and use of DRL is popular in Europe, and the US.[8] In Europe, the establishment and review of DRLs was introduced nearly a decade before the recommendation of international regulatory bodies i.e., 1997, and it is now strengthened and mandatory in every member state of the European Union.[9] A literature review on DRL data also shows that majority of work is done on it in 13 out of 15 European countries.[10]

DRL is defined as dose values that are not expected to be beyond routine/typical examinations of standard-sized patient groups or standard phantoms for a given diagnostic task.[11] The National DRL (NDRL) is the 75th percentile of the dose distribution, while the 50th percentile, which is the mean value within a facility, is used as the Local DRL (LDRL) and it should not exceed the NDRL.[12]

The DRLs are not a dose constraint or used for regulatory purposes; it is an investigation tool to identify unusually high dose levels. If the doses are consistently higher, then it is reviewed locally to identify faulty machines or examination protocols. The recommended dosimeter parameters for DRL monitoring during CT examinations are CT dose index volume (CTDIvol) and Dose Length Product (DLP).[3] The CTDI is a measure of dose from a single rotation of the gantry. The CTDI is a standard measurement of radiation dose from a CT scan, measured in mGy, and different CT scanners can be compared in terms of radiation output. CTDIw is a weighted average of doses across a single slice. The CTDIvol (mGy) is obtained as CTDIvol = CTDIw / Pitch.

DLP is the product of CTDIvol and scans length (DLP = CTDIvol x scan length) and is measured in mGy.cm. DLP can be used to quantify the total amount of radiation patients receive during a given scan and Effective Dose can be calculated by multiplication with a conversion factor table based on anatomy and age [E(mSv) = k x DLP].[10]

The current study was planned to set LDRL for multiple anatomical regions at a heavy-flow tertiary care hospital using DLP as a dosimeter parameter, and to compare it with international DRL (IDRL).

Materials and Methods

The retrospective study was conducted at the Radiology Unit of Lady Reading Hospital (LRH), Peshawar, Pakistan, and comprised dose data of patients who had CT scan between June 1 and August 31, 2018.

Data was collected after exemption from the institutional ethics review committee. The equipment used had been a 160-slice multidetector computed tomograph scanner (Toshiba Aquilion Prime), offering X-ray tube in high voltages of 80 kilovoltage (KV), 100KV, 120KV and 140KV, and was equipped with automatic exposure control (AEC) systems with which the X-ray tube current could be modulated during scanning in the helical mode. The scanner offered maximum tube current up to 600 milliampere (mA), having 80 proprietary PUREVision scintillator array detector rows, 0.5mm detector row size, and 896 detectors per row. The z-axis length wa40mm and it could acquire 80 slices per rotation (160 slices with a reconstruction algorithm) and a minimum gantry rotation time of 350ms.

Data included related to patients if either gender aged 16-79 years. CT examinations were performed at 120KV peak (KVP) with automatic mA modulation ranging from 200 to 250mA. CTDIvol and DLP values were displayed on the CT graphical user interface immediately after setting the technical parameters, like distance from the centre, slice interval (I), slice thickness (T), length of scan (L), total acquisition time of the scan, number of slices (N), pitch factor (P), mA and KVP. The parameters were based on standard protocols related to head, chest, abdomen-pelvis, triphasic, 3D musculoskeletal (MSK), kidney-ureter-bladder (KUB), and cardiac CT. Both CTDIvol and DLP values were calculated and displayed on CT console and were saved on the Digital Imaging and Communications in Medicine (DICOM) as well. DLP values calculated through this method were in good agreement ±5% compared to values calculated from phantoms studies.[13] The DLP was read from DICOM and entered into SPPS 20 for different regions. The mean, 50th and 75th percentiles were calculated. Institutional DRLs were based on the 50th percentile of the dose dispensed to all the patients The results were cross-tabulated and compared with IDRLs.

According to the iData Research analysis of the medical procedure, >75 million CT scans were done per 326 million population of the US in 2018.[14] Applying this 23% exposure to Pakistan population of 212 million in the same year, the adequate study sample was 768 with 99.9% confidence interval (CI).

Results

Of the 1001 scans, 143(14.2%) related to brain, 275(27.5%) abdomen-pelvis, 133(13.3%) KUB, 186(18.58%) thorax, 85(8.49%) triphasic, 126(12.58%) MSK, and 53(5.29%) cardiac CTA. The mean scan length of the three most frequent body regions was 14.5±1.3 cm for the brain, 21.8±3.2 cm for the chest, and 40±4.6 cm for the abdomen-pelvis.

The mean, 25th, 50th and 75th percentile values for DLP

Table-1: Institutional CT dose of 160-slicer in DLP (mGy.cm).

Region	Percentile			Mean±SD
	25th	50th	75th	
Brain	313	339	363	356±110.5
Abdomen Pelvis	264	298	374	351±190.3
Thorax	137	165	229	201±108.5
KUB	253	302	415	355±159.1
Triphasic	417	633	962	783±345.6
3D MSK	242	366	581	484±364.5
Cardiac CTA	196	403	677	445±277.5

CT: Computed tomography; DLP: Dose length product; KUB: Kidney-ureter-bladder;
MSK: Muscoskeletal, CTA: Computed tomography angiography; SD: Standard Deviation.

Table-2: Comparison with available international DRLs.

	Head/ Brain	Chest / HRCT	Abdomen pelvis	Multiphase Abdomen/triphasic	KUB	3D MSK	Cardiac CTA
Institutional 50th Percentile	339	165	298	633	302	366	403
Institutional 75th percentile	363	229	374	962	415	581	67
Singapore 50th Percentile[12]	980	255	515	1155			
Ireland[14]	940	390	60	1120			
United States[15)]	1120	610	850	1790			
Australia[16]	1000	450	700				
Japan[17]	1350	550	1000	1800	1410		
ICRP[3]	1050	650	780				
Iran 50th percentile[2]	658	99	333				403
Qatar 75th percentile[18]	1820	240	1820		550		370

DRL: Diagnostic reference level; HRCT: High-resolution computed tomography; KUB: Kidney-ureter-bladder;
3DMSK: Three-dimensional muscoskeletal; CTA: Computed tomography angiography; ICRP: International radiological protection commission.

were calculated, and the institutional DRLs for the CT unit were established as brain 339, abdomen-pelvis 298, thorax 165, KUB 302, triphasic 633, MSK 366 and cardiac 403 (Table 1).

Both 50th and 75th percentile values of dose length product for each individual body region was lower than international Diagnostic reference levels.

The institutional DRLs were compared with IDRLs and DLP values were lower than IDRLs (Table 2).

Discussion

The study is the first to work out institutional DRLs in Pakistan. The institutional DRLs were lowered compared to IDRLs.[2,3,12,14-18] In Singapore,[12] about 15,000 adult CT scans were evaluated in 2015, using five CT scanners. There was a significant difference in various CT scanners' doses due to differences in protocol and different CT vendors. The examinations performed with the Siemens 384-slice CT had the lowest mean CTDIvol and DLPs, due to the new detector and dose-saving features. The Philips 256-slice CT had the highest DLP in multiphase CT scans done. Siemens 64-slice CT without iterative reconstruction (IR) technique had the highest mean CTDIvol. The main difference compared to the current study is that it used multiple CT scans and included multiphase studies which could explain the high mean DLP.

An Irish pilot[15] study conducted for the establishment of DRL in four hospitals included nearly 35,000 patients with contributions from other sites requiring a minimum of 10 average-sized patients for each CT examination over a 12-week period. The study recorded CTDIvol and DLP from the CT console for the ease of collection. It selected nine examinations for the main survey, including spine, pulmonary angiogram (CTPA), paranasal sinuses, and omitted KUB. Measurements from three Toshiba scanners were excluded due to high DLPs. The reason for the higher DLP could be the use of machines of lower slices, ranging from 4 to 16 slices.

A US study[16] collected data for all diagnostic CT scans done in 2013 at 12 facilities associated with the University of California. The CT examinations were performed with 34 scanners from five manufacturers and all the machines used were between 8 and 64 slicers. The study variables like CTDI and DLP were extracted using Radimetric software. The median dose and interquartile range (IQR) were calculated separately for children and adults (age ≥14 years) and according to anatomical regions.

The current findings were also compared with studies done in Iran,[2] Australia,[17] Japan[18] and Qatar.[19]

The CT system at LRH was equipped with automatic exposure control just as was the case with other studies cited above, but the main difference is the DRLs in their cases were aggregated from various centres having various machines, which appears to be the main reason for the discrepancy in the findings. Older machines with lesser slices can also cause discrepancies. Besides, more physically robust and fatty patients in the developed countries compared to local population can also be an element, though it cannot be validated because data related to height and weight of the patients was not part of the study.

The limitation of the current study is that it was based on single-centre, single-machine data collected over 3 months. Besides, patient weight and height were not recorded, institutional DRLs for paediatric examinations was not included, and DLP values were not separately calculated for contrast and non-contrast CT examinations.

Conclusion

It is hoped that other institutions will feel encouraged to gather their own dose data in order to establish an NDRL which will ensure acceptable radiation dose to the patients.

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References

1. Berrington de González A, Mahesh M, Kim KP, Bhargavan M, Lewis R, Mettler F, et al. Projected cancer risks from computed tomographic scans performed in the United States in 2007. Arch Intern Med 2009; 169: 2071-7.

2. Jafari S, Ghazikhanlu SK, Karimi M, Khosravi H, Goodarzi R, Pourkaveh M. Establishment of Diagnostic Reference Levels for Computed Tomography Scanning in Hamadan. J Biomed Phys Eng 2020; 10: 792-800
3. Vañó E, Miller DL, Martin CJ, Rehani MM, Kang K, Rosenstein M, et al; Authors on behalf of ICRP. ICRP Publication 135: Diagnostic Reference Levels in Medical Imaging. Ann ICRP 2017; 46:1-144.
4. Boone JM, Strauss KJ, Cody DD, McCollough CH, McNitt-Gray MF, Toth TL. Size-specific dose estimates (SSDE) in pediatric and adult body CT examinations. Reort of AAPM Task Group 204. American Association of Physicists in Medicine; 2011.
5. Kanal KM, Butler PF, Sengupta D, Bhargavan-Chatfield M, Coombs LP, Morin RL. U.S. Diagnostic Reference Levels and Achievable Doses for 10 Adult CT Examinations. Radiology 2017; 284: 120-33.
6. Einstein AJ. Medical Radiation Exposure to the U.S. Population: The Turning Tide. Radiology 2020; 295: 428-9.
7. Tsapaki V, Aldrich JE, Sharma R, Staniszewska MA, Krisanachinda A, Rehani M, et al. Dose reduction in CT while maintaining diagnostic confidence: diagnostic reference levels at routine head, chest, and abdominal CT--IAEA-coordinated research project. Radiology 2006; 240: 828–34.
8. Brink JA, Miller DL. U.S. National Diagnostic Reference Levels: Closing the Gap. Radiology 2015; 277: 3-6.
9. Council of the European Union. Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure, and repealing Directive 84/466/Euratom. Off J No L. 1997;180.
10. Paulo G, Damilakis J, Tsapaki V, Schegerer AA, Repussard J, Jaschke W, et al. Diagnostic Reference Levels based on clinical indications in computed tomography: a literature review. Insights Imaging 2020; 11: 96.
11. Hadnadjev DR, Aranđić D, Stojanovic SS, Ciraj-Bjelac O, Božović P, Stanković JS. Patient doses in computed tomography: An assessment of local diagnostic reference levels in a large teaching hospital. Nucl. Technol. Radiat Protect. 2012; 27: 305–10.
12. Liang CR, Chen PXH, Kapur J, Ong MKL, Quek ST, Kapur SC. Establishment of institutional diagnostic reference level for computed tomography with automated dose-tracking software. J Med Radiat Sci 2017; 64: 82–9.
13. Tsalafoutas IA, Metallidis SI. A method for calculating the dose length product from CT DICOM images. Br J Radiol 2011; 84: 236–43.
14. iData Research. Over 75 million CT scans Are Performed Each Year and Growing Despite Radiation Concerns - iData Research. [Online] 2018 [Cited 2022 September 8]. Available from: URL: https://idataresearch.com/over-75-million-ct-scans-are-performed-each-year-and-growing-despite-radiation-concerns/
15. Foley SJ, McEntee MF, Rainford LA. Establishment of CT diagnostic reference levels in Ireland. Br J Radiol 2012; 85: 1390–7.
16. Smith-Bindman R, Moghadassi M, Wilson N, Nelson TR, Boone JM, Cagnon CH, et al. Radiation Doses in Consecutive CT Examinations from Five University of California Medical Centers. Radiology 2015; 277: 134–41.
17. Australian Radiation Protection and Nuclear Safety Agency. National Diagnostic Reference Level. 2016. [Online] 2016 [Cited 2022 May 15]. Available from: URL: http://www.arpansa.gov.au/services/ndrl/ndrlfactsheet.cfm.
18. Kanda R, Akahane M, Koba Y, Chang W, Akahane K, Okuda Y, et al. Developing diagnostic reference levels in Japan. Jpn J Radiol 2021;39: 307-14.
19. AlNaemi H, Tsapaki V, Omar AJ, AlKuwari M, AlObadli A, Alkhazzam S, et al. Towards establishment of diagnostic reference levels based on clinical indication in the state of Qatar. Eur J Radiol Open 2020; 7: 100282.