ASSESSMENT OF PATIENT RADIATION DOSE TO UPDATE LOCAL DRLs FROM NEWLY INSTALLED CT SYSTEMS

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Abstract. — **After the installation of two Computed Tomography (CT) systems between the year 2018 and 2020, at King Chulalongkorn Memorial Hospital, Bangkok, Thailand, the Local Diagnostic Reference Levels (LDRLs) for CT examinations had been established in 2022 for the optimization of radiation protection of patients. Other three CT systems were installed in the year 2022, 2024 and 2025, with more CT examinations on both anatomical and clinical indications. The objectives of this study are to assess the patient radiation dose and update the LDRLs for the optimization on patient dose and image quality. Patient radiation dose had been collected from all CT examinations at the Division of Diagnostic Radiology, Department of Radiology, King Chulalongkorn Memorial Hospital (KCMH), Thai Red Cross Society, in the year 2025. The data included the patients aged 18 years and above with the body weight between 45 and 75 (60 ± 15) kg. Eight common CT examinations based on the location region, include: 1) Brain 2) Brain including cervical spine 3) Neck 4) Chest 5) The angiography of the whole aorta 6) Upper abdomen multi - phases 7) Whole abdomen 8) Chest and whole abdomen. In addition, eight common CT examinations based on clinical diagnostic indications had also been collected as: 1) CTA carotid system for acute stroke 2) CTPA (CT pulmonary angiography) 3) Low-dose CT screening for lung cancer 4) HRCT 5) Coronary artery calcium scoring 6) Coronary CTA with retrospective ECG gating 7) Acute appendicitis 8) Urinary stone detection. Both results on LDRLs - Location and Clinical Indications based were compared to the National Diagnostic Reference Levels (NDRLs Thailand) updated in 2025. The updated LDRLs for most CT protocols in this study were lower than the NDRL CT, and close to the previous LDRL established in 2022.**

Keywords— **Diagnostic Reference Levels, Clinical Indication DRLs, Local DRL, National DRL, Computed Tomography.**

I. INTRODUCTION

The establishment of Diagnostic Reference Levels (DRLs) is one of the tools for controlling and optimizing the patient radiation dose from CT examinations [1-5]. DRLs serve as a benchmark for comparing patient radiation doses to the national or international standards, enabling the identification and timely revision of examination protocols according to unnecessary high radiation doses.

After the clinical applications of the new CT scanners, the patient radiation doses from various parameters, selected protocols, software functionality, and dose-reduction technologies should be considered and compared to the previous LDRLs for changes. As a result, the previously established LDRLs within the institution may no longer reflect the current clinical practice. Continued use of outdated LDRLs may therefore lead to inaccurate assessments of patient radiation dose.

Therefore, it is necessary to evaluate the patient radiation doses especially from the new CT systems to establish and update the LDRLs for the modern CT technology, to align with the recommendations from the International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) for the patient dose management [6-8]. Updated LDRLs with accurate information will help improving the quality of CT examinations, enhancing the patient safety, and supporting the long-term development on the effective use of radiation in the department.

This will enable us to evaluate the Local Diagnostic Reference levels (LDRLs) for all CT scanners in the hospital. LDRLs for CT examinations in 2025 will be compared to LDRLs for CT examinations in 2022, and the National Diagnostic Reference Levels (NDRLs, 2025) [9]. The results will provide further improvement and optimization of radiation dose management for the hospital.

II. MATERIALS AND METHODS

Study design and setting

The analytical, observational, retrospective study has been conducted at Department of Radiology, King Chulalongkorn Memorial Hospital. The Institutional Review Board, Faculty of Medicine Chulalongkorn University approved the COA No.0360/2026 IRB No.0017/69 title "Assessment of Patient Radiation Dose to Update Local DRLs from Newly Installed CT Systems". Patient radiation dose had been collected from all CT examinations performed at the Division of Diagnostic Radiology, Department of Radiology, King Chulalongkorn Memorial Hospital, in the year 2025. The study includes all patients aged 18 years and above with body weight between 45 and 75 (60 ± 15) kg. The study covers eight CT examination protocols of common anatomical region, with the number of examinations as shown in Table 1. Eight CT examination protocols of common clinical diagnostic indications, with the number of examinations are shown in Table 2.

Table 1 Eight CT examination protocols based on common anatomical regions or Location-based and number of examinations for each protocol

CT examination protocols	Number of Exams
1. Brain	5,312
2. Brain including cervical spine	239
3. Neck	1,128
4. Chest	6,749
5. CT angiography of whole aorta	186
6. Upper abdomen multi-phases	2,999
7. Whole abdomen	2,927
8. Chest and whole abdomen	5,516
Total CT Examinations	**25,056**

A total number of 27,790 examinations from 16 CT examination protocols were included in the study (Table1 and Table2). The radiation metric, Volumetric CT Dose Index, $CTDI_{vol}$, and Dose Length Product, DLP values were collected from the Dose Monitoring System (DMS), using the Radimetrics software (version 3.4.2), manufacturer Bayer, S/N HPE: SGH729XNK3.

The specification of five CT scanners serviced at the Division of Diagnostic Radiology, Department of Radiology, King Chulalongkorn Memorial Hospital, Thai Red Cross Society as shown in Table 3, are variety, depend on the technology between manufacturers and the year of installation, which affect the patient radiation dose. [10-12].

New CT scanners are typically equipped with advanced software and technologies designed for the patient dose reduction while maintaining the image quality for clinical interpretation by radiologists [13-14]. These technological differences may directly influence the LDRLs for CT examinations.

Table 2 Eight CT examination protocols based on clinical indications or Indication-based and number of examinations for each protocol.

CT examination protocols	Number of Exams
1. CTA carotid system for acute stroke	1,251
2. CTPA	419
3. Low-dose screening for lung cancer	88
4. HRCT	347
5. Coronary artery calcium scoring	103
6. Coronary CTA retrospective ECG gating	71
7. Acute appendicitis	64
8. Urinary stone detection	391
Total CT Examinations	**2734**

Table 3 Specifications of five CT Equipment at King Chulalongkorn Memorial Hospital, Thai Red Cross Society. (Mar 2026)

Specifications	Manufacturers				
	GE	Philips	GE	GE	Siemens
Model	Revolution CT EX	Incisive	Revolution CT Apex	Revolution CT Apex Elite	Somatom Force
Year of installation	2018	2020	2022	2024	2025
Detector rows	256	64	256	256	192 (96x2)
Maximum detector coverage (cm)	16	4	16	16	18.4
Detector element size (mm)	0.625	0.625	0.625	0.625	0.6
kV range	70 – 140	70 – 140	70 – 140	70 – 140	70 - 150
Dual energies	Ultrafast kVp switching	N/A	Ultrafast kVp switching	Ultrafast kVp switching	Dual Sources
keV range	40-140	N/A	40-140	40-140	40-190
Dose modulation	Smart mA Auto Prescription	3D Dose-Modulation (3D-DOM)	Smart mA Auto Prescription	Smart mA Auto Prescription	CARE Dose 4D

In 2025, Department of Medical Sciences, Ministry of Public Health, Thailand, updated and published NDRL for CT examinations conducted in diagnostic radiology for the $CTDI_{vol}$ and DLP (75th percentile). The NDRLs categorized on the location-based CT examinations in adults, comprise of eight examinations as shown in Table 4. The eight examination types of CT on clinical indication-based in adults of smaller examination numbers than the location based is shown in Table 5, resulting of 16 CT examination types in total.

Table 4 National Diagnostic Reference Levels (NDRLs) - CTDIvol and DLP (75th percentile), Location-based CT Examinations for adults in 2025 [9].

CT Examinations	CTDIvol (mGy)	DLP per phase (mGy·cm)	Total DLP per study (mGy·cm)
1. Brain	58.0	1,188	-
2. Brain including cervical spine	58.1	1,483	-
3. Neck	18.4	653	1,139
4. Chest	10.2	381	766
5. CT angiography of whole aorta	10.5	862	2,446
6. Upper abdomen multi-phases	11.8	392	1,536
7. Whole abdomen	12.5	631	2,059
8. Chest and whole abdomen	12.4	838	2,339

Table 5 National Diagnostic Reference Levels (NDRLs) - CTDIvol and DLP (75thpercentile), Indication-based CT examinations for adults in 2025[9].

CT Examinations	Phantom diameter (cm)	NDRLs Thailand	
		CTDIvol (mGy)	DLP (mGy·cm)
1. CTA carotid system for acute stroke			
Arterial phase (vertex to aortic arch)	32	15.4	601
	16	30.8	1,202
All phases	32	-	2,001
	16	-	4,002
2. CTPA			
Arterial phase	32	12.0	429
All phases	32	-	1,234
3. Low-dose screening for lung cancer			
Non-contrast phase	32	2.4	101
4. HRCT			
Supine, inspiration, helical mode	32	10.2	388
Supine, expiration, helical mode	32	8.8	314
All phases	32	-	693
5. Coronary artery			
Calcium scoring	32	7.8	118
6. Coronary CTA			
Retrospective ECG gating	32	46.8	808
All phases	32	-	1,197
7. Acute appendicitis			
Single phase	32	12.2	491
All phases	32	-	902
8. Urinary stone detection			
Non-contrast phase	32	12.8	621

III. RESULTS

From the collected data of patients who underwent CT examinations that met the predefined inclusion criteria using five CT systems, 27,790 examinations covering 16 protocols were included in 2025. Statistical analysis was performed to determine the 50th percentile (median) values of CTDIvol (mGy) and DLP (mGy·cm) for examinations protocols based on common anatomical regions (Location-based) and protocols based on clinical indications (Indication-based). The Local Diagnostic Reference Levels (LDRLs) was updated and presented in Tables 6 and 7.

Table 6 Comparison of the Local DRLs (50th percentile) at KCMH to the NDRLs (75th percentile) Thailand, Japan, Korea, USA (ACR DIR) and RDRLs (50th percentile) EU for Location-based CT Examinations for adults in 2025 for CTDIvol (mGy) and DLP (mGy.cm).

CT Examinations	LDRL KCMH (50th percentile) 2025		LDRL KCMH (50th percentile) 2022		NDRLs Thailand (75th percentile) 2025		NDRLs Japan (75thpercentile) 2025		NDRLs Korea (75th percentile) 2021		NDRLs USA ACR DIR (75th percentile) 2017		RDRL EU (50th percentile of NDRLs) 2021	
	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)	$CTDI_{vol}$ (mGy)	DLP (mGy·cm)
1. Brain	50.0	1,090	46.9	988	58.0	1,188	67	1,260	52.2	970	57	1011	48	1386
2. Brain including cervical spine	46.9	1,774	-	-	58.1	1,483	-	-	-	-	-	-	-	-
3. Neck	14.0	496	15.5	466	18.4	653	-	-	13.4	597	20	572	-	-
4. Chest	7.2	284	9.3	371	10.2	381	11	430	7.6	324	16	596	9	364
5. CT angiography of Whole Aorta	8.8	599	-	-	10.5	862	-	-	-	-	-	-	-	-
6. Upper Abdomen Multi-phases	11.6	369	10.5	291	11.8	392	13	-	9.3	-	-	-	9	-
7. Whole Abdomen	11.5	584	9.9	437	12.5	631	14	720	8.9	474	19	995	9	874
8. Chest and Whole Abdomen	11.4	808	9.3	606	12.4	838	13	940	-	-	-	-	-	-

Table 7 Comparison of the LDRL (50th percentile) at KCMH to the NDRLs (75th percentile) Thailand, Japan, Korea, USA (ACR DIR) and RDRLs EU on Indication-based CT Examinations for adults in 2025 - CTDIvol (mGy) and DLP (mGy.cm).

CT Examinations	Phantom diameter (cm)	LDRLs (KCMH) (50th percentile) 2025		LDRLs (KCMH) (50th percentile) 2022		NDRLs Thailand (75th percentile) 2025		NDRLs Japan (75th percentile) 2025		NDRLs Korea (75th percentile) 2021		NDRLs USA ACR DIR (75th percentile) 2017		RDRL EU (50th percentile of NDRLs) 2021	
		CTDIvol (mGy)	DLP (mGy·cm)	CTDIvol (mGy)	DLP (mGy·cm)	CTDIvol (mGy)	DLP (mGy·cm)	CTDIvol (mGy)	DLP (mGy·cm)	CTDIvol (mGy)	DLP (mGy·cm)	CTDIvol (mGy)	DLP (mGy·cm)	CTDIvol (mGy)	DLP (mGy·cm)
1. CTA carotid system for acute stroke															
Arterial phase (vertex	32	9.5	391	9.4	385	15.4	601	-	-	-	-	-	-	-	-
to aortic arch)	16	-	-	-	-	30.8	1,202	-	-	-	-	-	-	-	-
All phases	32	-	-	-	-	-	2,001	-	-	-	-	-	-	-	-
	16	-	-	-	-	-	4,002	-	-	-	-	-	-	-	-
2. CTPA															
Arterial phase	32	9.2	321	12.2	389	12.0	429	12.0	-	-	-	18.0	557	8.0	628
All phases	32	-	-	-	389	-	1,234	-	2,300	-	-	-	-	-	-
3. Low-dose screening for lung cancer															
Non-contrast phase	32	2.9	128	3.6	252	2.4	101	-	-	2.7	110	-	-	-	-
4. HRCT															
Supine inspiration helical mode	32	7.6	291	6.7	259	10.2	388	-	-	-	-	-	-	-	-
Supine expiration helical mode	32	1.9	63	-	-	8.8	314	-	-	-	-	-	-	-	-
All phases		-	-	-	307	-	693	-	-	-	-	-	-	-	-
5. Coronary artery															
Calcium scoring	32	3.7	60	2.7	43	7.8	118	8.0	160	5.9	96	-	-	4.0	81
6. Coronary CTA															
Retrospective ECG gating	32	44.7	815	59.5	1,090	46.8	808	57	940	-	-	-	-	-	-
Prospective ECG gating		21.5	307	23.1	301	-	-	49	770	19.2	327	-	-	25.0	459
All phases	32	-	-	-	-	-	1,197	-	-	-	-	-	-	-	-
7. Acute appendicitis															
Single phase	32	10.4	387	11.3	430	12.2	491	-	-	-	-	-	-	-	-
All phases	32	-	-	-	430	-	902	-	-	-	-	-	-	-	-
8. Urinary stone detection															
Non-contrast phase	32	3.5	193	7.2	359	12.8	621	-	-	-	-	-	-	-	-

IV. DISCUSSION

The Department of Medical Sciences has updated the National Diagnostic Reference Levels (NDRLs) for diagnostic imaging using computed tomography (CT) in the year 2025, for both Location-based and Indication-based categories, in order to ensure that the reference values are up-to-date and standardized. This update aims to provide consistent benchmarks for diagnostic dose reference values, protect the patients from the high radiation dose, promote the safe use of radiation, and prevent radiation hazards in accordance with established standards [15-18].

At King Chulalongkorn Memorial Hospital, The Thai Red Cross Society, several high-performance CT systems are in clinical service. To maintain institutional standards and support proper and appropriate radiation dose management, the hospital has therefore updated its local diagnostic reference levels to reflect the performance of these newly installed CT systems. The updated LDRL (2025) were subsequently compared to the previous LDRL established in 2022 and the NDRLs Thailand announced by the Department of Medical Sciences in 2025, across all 16 key protocols, for both Location-based and Indication-based examinations.

The results showed that the LDRLs KCMH for most examination protocols in this study were lower than the NDRLs Thailand and close to previous LDRL KCMH established in 2022. In addition, the results were compared to NDRLs in Asian countries, such as Japan and Korea [19-20]. The LDRL 2025 (KCMH) was lower than NDRLs reported by Japan in 2025, but $CTDI_{vol}$ Neck, Upper Abdomen and Whole Abdomen were higher than NDRLs Korea in 2021.

Furthermore, when compared LDRLs KCMH with the US and EU, the LDRLs (KCMH) was lower than NDRL reported by American College of Radiology (ACR) (2017) [21]. CTDIvol Brain, Upper Abdomen and Whole Abdomen were higher than the European Union (EU) estimated at 50th percentile (median) of NDRL (2021) [22], as shown in Tables 6 and 7.

In this study, LDRL for brain including cervical spine protocol on location based, the CTDIvol is lower than the NDRLs Thailand; however, the DLP is higher than the NDRLs Thailand due to the long scan length. Number of phases is another parameter increasing the radiation metric, DLP. Therefore, the training and education should be provided to CT personnel to raise awareness of the importance of appropriate scan range and number of phases

and to establish suitable anatomical reference points for the organs being examined in order to address this issue. For Indication-based, most protocols particularly coronary artery examination for calcium scoring and urinary stone detection showed LDRLs are relatively lower than the NDRLs Thailand and other countries. The image quality remained sufficient for radiologists to interpret the images accurately. This result is attributed to the performance of modern CT scanners, equipped with advanced dose-reduction software and technologies that enhance image quality while reducing radiation exposure.

V. CONCLUSION

The installation of five CT scanners at the Department of Radiology, KCMH, from 2018 to 2025 led to the establishment of LDRLs CT in 2022 and updated in 2025 for both location and clinical indication based. The LDRL clinical indications showed the radiation doses tailored to specific disease areas, maximize patient benefits and appropriateness of care. It is worth noting that besides considering anatomical-based DRLs, determining radiation doses tailored to specific disease areas can maximize patient benefits and appropriateness of care. This approach leads to better outcomes for patients, as it ensures appropriate radiation doses while maintaining diagnostic efficacy.

It is also important to update the clinical practices and provide the continuous training for personnel to ensure proper use of the technology and to raise awareness of appropriate radiation dose management for patients. Such efforts will contribute to improving healthcare services and promoting radiation safety in the near future.

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