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The Establishment of Institutional Diagnostic Reference Levels (DRLs) in the Cipto Mangunkusumo Hospital

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ABSTRACT

Institutional diagnostic reference levels are used for quality assurance in radiology departments. The purpose of this study was to establish an institutional diagnostic reference level (DRL) and to provide a practical tool in diagnostic radiology and nuclear medicine. For each type of procedure/examination, it needs at least 20 patients. The patients with regular size (average body size is 65 ± 10 kg for adult patients and 15±15 kg for pediatric patients) were enrolled in this project. The 75 percentile values of doses were used as institutional DRLs. For nuclear medicine, the administered activities was based on the dose of activity to produce a good image. The DRL values were obtained for general radiography, nuclear medicine, mammography, CT examination, and interventional radiography. The DRL's result was compared to national DRL (NDRL) and values in other countries. The DRL values for general radiography in this study are higher compared to NDRL and Japanese study. The administered activities (MBq) for nuclear medicine in this study are higher compared to European Commission but lower when compared to a Japanese study. The DRL values for mammography in this study are higher compared to ARPANSA; however, they are lower than NDRL and UK studies. The DRL values for CT examination in this study are higher compared to Netherland, Canadian, and USA studies but lower than NDRL. The DRL values in interventional radiography (IR) in this study are lower compared to the IAEA study. This finding indicates that it is still necessary to optimize procedures in the future. The established institutional DRL values can be used as a tool for optimization.

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INTRODUCTION

Optimization is a pillar in the system of radiological protection and safety as defined by the International Commission on Radiological Protection (ICRP) %1]. However, the principle of optimization is complex, and to further clarify the issue, optimization is described as a process depending on various factors [2]. The ICRP describes the optimization for medical exposures as follows: 'Optimization is best described as the management of radiation dose to the patient to be commensurate with the medical purpose' [3]. The radiation dose varies significantly among different diagnostic radiology applications and patients [4]. One core activity in optimization is the management of radiation dose to the patient [5]. One practical tool to manage the radiation dose for diagnostic X-ray examination and nuclear medicine examination is diagnostic reference levels (DRLs) [5].

A DRL is an investigation level used as a tool to aid in the optimization of protection in the medical exposure of patients for diagnostic and interventional procedures. It is used in medical imaging with ionizing radiation to indicate whether, in routine conditions, the amount of radiation used for a specified procedure is unusually high or low for that procedure. For nuclear medicine, the

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administered activity (amount of radioactive material), or preferably the administered activity per unit of body weight, is used. Institutional DRLs may be set for procedures when no national DRL is available, or where there is a national value but institutional equipment or techniques have enabled a greater degree of optimization to be achieved so that a value less than the corresponding national DRL can be implemented [6-8]. The systems of DRL are slightly different in different countries, but in Europe most systems rely on radiation dose quantities derived for a set of standardized diagnostic procedures concerning a standardized patient [9].

Management of the patient's radiation dose for each type of examination is very important. Currently, the perspective is more patient-oriented by communicating radiation risk and evaluating the radiation dose received by the patient at each health service. This has become the basis for the need for optimization in radiology. Assessment of DRLs is one of the quality assurance programs in diagnostic radiology [7-10].

Cipto Mangunkusumo Hospital is a national hospital center in Indonesia, hence establishment institutional DRL at the hospital is essential. The use of institutional DRL in our hospitals is to create guidelines for good clinical practice in medical imaging, to achieve optimal values for the medical imaging protocol, and to prevent unnecessary patient radiation exposure. Therefore, this study aimed to establish institutional DRL and to provide a practical tool in diagnostic radiology and nuclear medicine.

METHODOLOGY

DRLs for general radiography and nuclear medicine have been established at Cipto Mangunkusumo hospital since 2019 followed by mammography, computed tomography (CT), and interventional radiography in 2020. The survey was conducted by collecting data for each type of examination and type of imaging procedure using ionizing radiation from 10 service units in this hospital from March 2019 to April 2020.

The steps in determining our DRL were as follows: *First*, identifying the procedure to be assigned the DRL value. Priority was given to examinations with the highest frequency. *Second*, calibration of all dosimeters used regularly. The accuracy of the doses from the X-ray system was regularly verified by medical physicists using Unfors Raysafe X2. The output of the X-ray tube for each piece of equipment was measured according to the IAEA TRS 457 protocol. The variation between the measured and displayed values was within ± 20 %. *Third*, recording the radiation quantity of each available procedure for each type of medical imaging modality. The equipment used in this study was generally has equipped with digital image capture. The DRL quantity used in this study included the entrance surface air kerma ($K_{a,e}$) for general radiography measured in mGy, administered activity for nuclear medicine measured in MBq, mean glandular dose (D_G) for mammography measured in mGy, volume CT dose index ($CTDI_{vol}$) and dose-length product (DLP) for CT measured in mGy and mGy.cm [9,11], and air kerma-product area (P_{KA}) for interventional radiography measured in Gy cm^2. *Fourth*, data collection for DRL values. *Fifth*, collection of patient data using the IAEA data collection form. The form 1 was used to provide data for the X-ray unit and form 2 to collect data for patient examinations and dose calculation [6,12,13]. Separate worksheets were provided for adult and pediatric examinations.

The DRL was calculated by 75th percentile of doses or administered activities using the Microsoft Excel. In addition, medians of administered activities were calculated for nuclear medicine, and means and medians of doses were also calculated for CT, mammography and interventional radiography.

General radiography

There were 11 examination types of general radiography, namely skull PA, skull lateral, chest PA, chest lateral, thoracic spine AP, thoracic spine lateral, lumbal AP, lumbal lateral, abdomen AP, femur AP, and hip joint AP. Entrance surface air kerma ($K_{a,e}$) of at least 20 patients for each examination type of general radiographic examination for each machine were calculated. The total number of patients was 11 × 20 patients = 220 patients.

Data collection form included date of examination, examination type, projection, patient data, radiographic technique, detector size, exposure data, image quality scoring performed by a radiologist: 1) fully acceptable; 2) acceptable with remarks; 3) unacceptable (to be repeated), patient thickness, and x-ray tube output measurement.

The entrance surface air kerma (ESAK) was calculated by following the IAEA TRS 457 [12]. *First*, estimation of the incident air kerma (K_i) was based on exposure parameters (tube voltage, tube current–exposure time product, field size, etc.) recorded from the patient examination using Eq. (1).

$$K_i = Y(d) \times P_{It} \times \left(\frac{d}{d_{FTD} - t_p}\right)^2 \quad (1)$$

where *Y(d)* is the X-ray output measured at distance *d* from tube focus, P_{it} is the tube loading for every patient taken from console, d_{FTD} is the tube focus to patient support distance, and t_p is patient thickness. *Second*, ESAK was calculated as multiplication of the incident air kerma by the appropriate backscatter factor (B) [13] using Eq. (2).

$$ESAK = K_i \times B \quad (2)$$

Nuclear medicine

There were 26 examination types for nuclear medicine, and administered activities of 20 patients for each examination type were calculated. The total number of patients was 26 × 20 patients = 520 patients. Data collection form including date of examination, patient data, clinical indication, image quality score were collected.

This study used the activity given in the MBq for nuclear medicine imaging using a given radiopharmaceutical (e.g myocardial perfusion with ^{99m}Tc-tetrofosmin/MIBI) [14]. The activity was measured before an administered dose was given to the patient. The DRL value for nuclear medicine was determined based on the dose of the administered activity to produce a good image, adjusted to standard equipment, and procedure settings.

Mammography

Mean glandular doses (mGy) of 50 patients for each projection of mammography were calculated. There were two projections, namely mediolateral-oblique (MLO) and cranio-caudal (CC) projection for both breast. The total patients was 2 x 50 patients = 100 patients.

Data collection for this study included the date of examination, projection, patient data, compressed breast thickness, image quality score, radiographic technique (target/filter combination), selection of exposure parameters, image detector, exposure data, HVL, focus to breast surface distance, X-ray tube output, incident air kerma (*Ki*) (mGy), conversion factor from incident air kerma to MGD (*g* factor), correction factor for any difference in breast composition from 50 % glandularity (*c* factor), target-filter combination (*s* factor).

The mean glandular dose (D_G) was calculated from the incident air kerma (*Ki*) and conversion coefficients of *g*, *c*, and *s* for the HVL values and the corresponding breast thickness with an assumed breast glandular of 50 %. The conversion coefficients depend on the target/filter combination, tube voltage used, and HVL of the X-ray [12] using Eq. (3).

$$D_G = K_i \times g \times c \times s \quad (3)$$

Computed tomography

There were three types of CT examinations, i.e. head, chest, and abdomen. The CT examinations were divided into pediatric (age: 0-4 year and 5-14 year) and adult patients (≥ 15 year). Each CT examination involved 30 adult patients and 20 pediatric patients. The total number patients was 3 × 30 patients + 6 × 20 patients = 210 patients.

$CTDI_{vol}$ and DLP were taken from CT console. The data collection form included the date of examination, patient data, procedure type, and clinical indication, the contrast material used, exposure parameters, scanning parameters, protective shielding used, and image quality scoring to be done by a radiologist. There was additional information for pediatric patients regarding immobilization, sedation used and someone to assist patients in pediatric patient rooms.

Interventional radiography

There were 8 types of interventional radiography, namely percutaneous coronary intervention (PCI), coronary angiography (CA), trans arterial chemo embolization (TACE), Brain-Digital Subtraction Angiography, arteriography, catheterization, electrophysiology ablation, and endovascular treatment of abdominal aortic aneurysms (EVAR). Air kerma-area product (P_{KA}) of at least 30 patients for each examination type were collected. The total number of patients was 8 × 30 patients = 240 patients.

The air kerma-area product (P_{KA}) data were recorded from the interventional radiography machine. Data collection form included date of examination, procedure type, patient data, protocol, and complexity of the procedure.

RESULTS AND DISCUSSION

All radiological examinations are confirmed to have been validated and accepted for clinical needs. The DRL values for general radiography using the ESAK quantities are shown in Table 1. The highest ESAK value obtained for femur AP projection is 58 mGy and the lowest ESAK value for chest PA is 0.4 mGy.

The Administered activities (MBq) for nuclear medicine examinations are shown in Table 2. The highest administered activities has been found for Myocardial perfusion-1 day rest and stress protocol using ^{99m}Tc-Tetrofosmin/MIBI about 1520 MBq and the lowest administered activities about 40 MBq for oesophageal reflux, oesophageal transit, and small bowel transit.

The DRL value for mammography using the mean glandular dose (D_G) quantities is shown in Table 3. The highest D_G value obtained for Mediolateral-Oblique (MLO) View is 1.5 mGy (Grid) and the lowest D_G value for Cranio-Caudal (CC) View is 1.1 mGy.

Table 1. DRLs for general radiography of adult patients.

X-ray projection	Age	ESAK (mGy)
		Third Quartile
Skull PA	Adult (≥ 15 years)	5.0
Skull Lateral		3.0
Chest PA	Adult (≥ 15 years)	0.4
Chest Lateral		1.5
Thoracic Spine AP	Adult (≥ 15 years)	7.0
Thoracic Spine Lateral		20
Lumbal AP	Adult (≥ 15 years)	10
Lumbal Lateral		30
Abdomen AP	Adult (≥ 15 years)	10
Femur AP	Adult (≥ 15 years)	58
Hip Joint AP	Adult (≥ 15 years)	10

Table 2. Administered activities (MBq) for nuclear medicine.

Category	Examination	Radiopharmaceutical	Procedure	Administered activities (MBq)	
				Median	Third Quartile
Cardiology	*Cardiac first pass*	^{99m}Tc - pertechnetate,red cells	IV	875	930
	Cardiac L/R shunt	^{99m}Tc - pertechnetate	IV Bolus	550	900
	Cardiac R/L shunt	^{99m}Tc - MAA	IV	150	185
	Gated blood pool scan (MUGA)	^{99m}Tc - red cells	IV	990	1030
	Myocardial perfusion-single-phase	^{99m}Tc - tetrofosmin/MIBI	IV	475	620
	Myocardial perfusion-1 day rest +	^{99m}Tc - tetrofosmin/MIBI	IV	1400	1520
Endocrine	Parathyroid	^{99m}Tc - tetrofosmin/MIBI	IV	820	900
	Parathyroid with subtraction method	^{99m}Tc - pertechnetate, tetrofosmin/MIBI	IV	75	220
	Thyroid	^{99m}Tc - pertechnetate	IV	210	215
Gastrointestinal	Localization of intestinal bleeding	^{99m}Tc - red cells	IV	1000	1000
	Gastric emptying time test	^{99m}Tc - colloid DTPA	Oral	43	44
	Oesophageal reflux (GERD test)	^{99m}Tc - colloid DTPA	Oral	40	40
	Oesophageal transit	^{99m}Tc - colloid DTPA	Oral	40	40
	Small bowel transit	^{99m}Tc - colloid DTPA	Oral	40	40
	Meckel's diverticulum scan	^{99m}Tc - pertechnetate	IV	400	400
	Salivary Gland	^{99m}Tc - pertechnetate	IV	185	200
Genitourinary	cystogram	^{99m}Tc - pertechnetate	Bladder	50	94
	Kidney Cortical DMSA	^{99m}Tc - DMSA	IV	150	200
	Renogram DTPA	^{99m}Tc - DTPA	IV	400	500
	Renogram MAG3	^{99m}Tc - MAG3	IV	270	305
	Kidney Transplant	^{99m}Tc - DTPA,MAG3	IV	300	400
	Testicles	^{99m}Tc - pertechnetate	IV	400	600
Hepatobilier	Hepatobilier	^{99m}Tc - HIDA,DISIDA,DIDA	IV	205	210
	Hemangioma / RBC scan	^{99m}Tc - red cells	IV	900	1000
	Liver / spleen	^{99m}Tc - colloid	IV	200	200
	Liver Transplant	^{99m}Tc - HIDA,DISIDA	IV	185	200

Table 3. DRLs for mammography.

Mammographic view	Age		Target/Filter	Mean glandular dose/D_G (mGy)		
				Mean	Median	Third Quartile
Mediolateral-Oblique (MLO)	Adult	(≥15 years)	W/Rh	1.4 (Grid)	1.2 (Grid)	1.5 (Grid)
Cranio- Caudal (CC)	Adult	(≥15 years)	W/Rh	1.1 (Grid)	1.0 (Grid)	1.1 (Grid)

DRL for CT examination of adult patients using volume CT dose index ($CTDI_{vol}$) and dose length product (DLP) are shown in Table 4. The highest $CTDI_{vol}$ value obtained for head CT is 65 mGy and the lowest $CTDI_{vol}$ value for chest CT is 12 mGy. Meanwhile, the highest DLP value for CT Abdomen is 1562 mGy.cm and the lowest DLP value for chest CT is 468 mGy.cm.

Table 4. DRL for CT examination of adult patients.

CT examination	Age	$CTDI_{vol}$ (mGy)			DLP (mGy.cm)		
		Mean	Median	Third Quartile	Mean	Median	Third Quartile
CT head	Adult (≥ 15 years)	57	56	65	1534	1025	1274
CT chest	Adult (≥ 15 years)	11	10	12	411	427	468
CT abdomen	Adult (≥ 15 years)	36	34	46	1302	1288	1562

a. The 16 cm diameter phantom is used for head examination, and the 32 cm diameter phantom is used for body examination.
b. CT Examination with contrast.
c. Uncertainty: 5 %. The uncertainty is based on the standard uncertainty multiplied by the coverage factor k = 2, at a confidence level of about 95 %.

The DRL for CT examination in pediatric patients is shown in Table 5. The highest $CTDI_{vol}$ value for head CT (5-14 years) is 48 mGy and the lowest $CTDI_{vol}$ value for chest CT (0-4 years) is 3.7 mGy. While the highest DLP value for abdominal CT (5-14 years) is 908 mGy.cm and the lowest DLP value for chest CT (0-4 years) is 85 mGy.cm.

Table 5. DRLs for CT examination of pediatric patients.

CT Examination	Age	$CTDI_{vol}$ (mGy)			DLP (mGy.cm)		
		Mean	Median	Third Quartile	Mean	Median	Third Quartile
CT Head	0-4 years	23	22	25	435	327	449
	5-14 years	34	32	48	756	659	884
CT Chest	0-4 years	3.5	3.5	3.7	69	62	85
	5-14 years	8	6	12	337	259	526
CT Abdomen	0-4 years	11	9	12	199	185	208
	5-14 years	16	14	31	645	317	908

a. The 16 cm diameter phantom is used for head examination, and the 32 cm diameter phantom is used for body examination.
b. CT Examination with contrast.
c. Uncertainty: 5 %. The uncertainty is based on the standard uncertainty multiplied by the coverage factor k = 2, at a confidence level of about 95 %.

DRLs for interventional radiography of adult patients using the air kerma-area product (P_{KA}) are shown in Table 6. The highest air kerma-area product (P_{KA}) value obtained for Percutaneous Coronary Intervention (PCI) is 101 mGy and the lowest air kerma-area product (P_{KA}) value for Endovascular treatment of abdominal aortic aneurysms (EVAR) is 28 mGy.

Table 6. DRLs for interventional radiography.

Type of examination	Age	P_{KA} (Gy.cm^2)		
		Mean	Median	Third Quartile
Percutaneous Coronary Intervention (PCI)	Adult (≥ 15 years)	77	67	101
Coronary Angiography (CA)	Adult (≥ 15 years)	74	57	96
Trans Arterial Chemo Embolization (TACE)	Adult (≥ 15 years)	24	21	28
Brain -Digital Subtraction Angiography	Adult (≥ 15 years)	38	39	42
Arteriography	Adult (≥ 15 years)	26	26	32
Catheterization	Adult (≥ 15 years)	33	20	41
Electrophysiology Ablation	Adult (≥ 15 years)	58	54	74
Endovascular treatment of abdominal aortic aneurysms (EVAR)	Adult (≥ 15 years)	22	26	28

Uncertainty: 5 %. The uncertainty is based on the standard uncertainty multiplied by the coverage factor k = 2, at a confidence level of about 95 %.

One practical tool to optimize the radiation dose for diagnostic X-ray examination and nuclear medicine examination is by implementing the DRL [6], which was introduced by ICRP. It is a beneficial tool for the optimization process [15-17].

The institutional DRLs in this study were calculated using the distribution of doses in a sample of patients at least 20 patients for each type of procedure/examination. The median values of data collected were calculated, and the 75 percentile values were calculated and used as DRL values. The ICRP also emphasizes that DRLs should not be applied to individual patients [7]. The reference level should reflect the current radiation dose level. So, the level must be adapted to current practices, representing the number of practices involved when setting up the reference level.

Table 7 shows the DRL comparison for general radiography with the National Diagnostic Reference Level (NDRL) [18] and Japanese study [19]. The DRL values for general radiography in this study are higher compared to NDRL and those of Japanese study. Differences in radiation dose can be caused by the performance of the equipment, differences in sample size, and operator skills. This finding indicates that optimization needs to be done in our institution.

Table 7. DRLs for general radiography compared to NDRL and other international studies.

X-ray projection	This study	NDRL [18]	Japan [19]
	ESAK (mGy)	ESAK (mGy)	ESAK (mGy)
Skull PA	5.0	1.3	3.0
Skull lateral	3.0	1.3	2.0
Chest PA	0.4	0.6	0.3
Chest Lateral	1.5	0.5	-
Thoracic Spine AP	7.0	1.5	3.0
Thoracic Spine Lateral	20	1.9	7.0
Lumbal AP	10	3.2	4.0
Lumbal Lateral	30	3.7	11
Abdomen AP	10	2.6	3.0
Femur AP	58	-	-

Table 8 shows the administered activities (MBq) for nuclear medicine compared to other international studies. The administered activities (MBq) for nuclear medicine in this study for myocardial perfusion rest and stress ^{99m}Tc - tetrofosmin/MIBI is 1520 MBq, higher than the Japanese study and EC. The parathyroid ^{99m}Tc - tetrofosmin/MIBI is 900 MBq and the renogram ^{99m}Tc - DTPA is 500 MBq, which are higher than the Japanese study. The renogram ^{99m}Tc - MAG3 is 305 MBq, and it is still higher compared to the EC study. This finding indicates that it is still necessary to optimize nuclear medicine procedures in the future, keeping the patient's radiation dose as low as possible but still providing the necessary information for clinical needs. The Myocardial perfusion ^{99m}Tc - tetrofosmin/MIBI single-phase, parathyroid with subtraction method, thyroid, localization of intestinal bleeding, Meckel's diverticulum scan, salivary gland, renogram ^{99m}Tc - MAG3, and hepatobiliary have a lower value of 620 MBq, 220 MBq, 215 MBq, 1000 MBq, 400 MBq, 200 MBq, 305 MBq, and 210 MBq, respectively, compared to the Japanese study.

Table 8. Administered activities (MBq) for Nuclear Medicine compared to other international studies.

Category	Examination	Radiopharmaceutical	Procedure	This Study (MBq)	Japan (MBq)[19]	EC (MBq)[9]
Cardiology	*Cardiac first pass*	^{99m}Tc - pertechnetate,red cells	IV	930	-	-
	Cardiac L/R shunt	^{99m}Tc - pertechnetate	IV Bolus	900	-	-
	Cardiac R/L shunt	^{99m}Tc - MAA	IV	185	-	-
	Gated blood pool scan (MUGA)	^{99m}Tc - red cells	IV	1030	-	-
	Myocardial perfusion- single phase	^{99m}Tc - tetrofosmin/MIBI	IV	620	900	-
	Myocardial perfusion-1 day rest and stress	^{99m}Tc - tetrofosmin/MIBI	IV	1520	1200	1200
Endocrine	Parathyroid	^{99m}Tc - tetrofosmin/MIBI	IV	900	800	-
	Parathyroid with subtraction method	^{99m}Tc - pertechnetate, tetrofosmin/MIBI	IV	220	300	-
	Thyroid	^{99m}Tc - pertechnetate	IV	215	300	-
Gastrointestinal	Localization of intestinal bleeding	^{99m}Tc - red cells	IV	1000	1040	-
	Gastric emptying time test	^{99m}Tc - colloid DTPA	Oral	44	-	-
	Oesophageal reflux (GERD test)	^{99m}Tc - colloid DTPA	Oral	40	-	-
	Oesophageal transit	^{99m}Tc - colloid DTPA	Oral	40	-	-
	Small bowel transit	^{99m}Tc - colloid DTPA	Oral	40	-	-
	Meckel's diverticulum scan	^{99m}Tc - pertechnetate	IV	400	500	-
	Salivary Gland	^{99m}Tc - pertechnetate	IV	200	370	-
Genitourinary	Cystogram	^{99m}Tc - pertechnetate	Bladder	94	-	-
	Kidney Cortical DMSA	^{99m}Tc - DMSA	IV	200	-	-
	Renogram DTPA	^{99m}Tc - DTPA	IV	500	400	-
	Renogram MAG3	^{99m}Tc - MAG3	IV	305	400	100
	Kidney Transplant	^{99m}Tc – DTPA,MAG3	IV	400	-	-
	Testicles	^{99m}Tc - pertechnetate	IV	600	-	-
Hepatobilier	Hepatobilier	^{99m}Tc – HIDA,DISIDA,DIDA	IV	210	260	-
	Hemangioma / RBC scan	^{99m}Tc - red cells	IV	1000	-	-
	Liver / spleen	^{99m}Tc - colloid	IV	200	180	-
	Liver Transplant	^{99m}Tc - HIDA,DISIDA	IV	200	-	-

Table 9 shows the DRL for mammography in this study compared to NDRL, ARPANSA [20], and UK [21]. The DRL values for mammography in this study for Mediolateral-oblique (MLO) and Cranio-caudal (CC) are 1.5 mGy and 1.2 mGy higher compared to ARPANSA (MLO: 1.3 mGy and CC: 0.9 mGy). However, it has a lower DRLs value compared to NDRL (MLO:- and CC: 3 mGy) and UK studies (MLO : 2.1 mGy and CC: 2 mGy). This might occur due to the well-functioning performance of the equipment and good operator skills.

Table 9. DRLs for Mammography compared to NDRL and other international studies.

Mammographic View	This Study	NDRL [18]	ARPANSA [20]	UK [21]
	D_G(mGy)	D_G(mGy)	D_G(mGy)	D_G(mGy)
Mediolateral-Oblique (MLO)	1.5	-	1.3	2.1
Cranio- Caudal (CC)	1.2	3.0	0.9	2.0

Table 10 shows the DRL for adult CT examinations compared to NDRL and Netherland [22], Canada [23], and the USA [24]. The DRL values for CT examination in this study for CT head, CT chest and CT abdomen are higher compared to Netherland, Canadian, and USA studies. However, the DRLs value for CT head and chest is lower than the value in NDRL.

Table 10. DRLs for adult CT examination compared to NDRL and other international studies.

Procedure	This study		NDRL[18]		Netherland[22]		Canada[23]		USA[24]	
	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP
CT head	65	1274	65	1400	-	936	79	1302	57	962
CT chest	12	468	14	759	-	346	14	521	12	445
CT abdomen	46	1562	20	1164	-	-	18	874	16	781

Table 11 shows the DRL for pediatric CT examination compared to NDRL and EC [9]. The DRL values for CT head (5-14 years) in this study are higher compared to EC. However, the DRLs value for CT Head and Abdomen (0-4 years) is lower compared to NDRL. Due to the sensitivity of pediatric patients to X-rays and the difference in body size, it is necessary to survey the DRLs in pediatric and adult patients separately [25]. The higher DRL found in this study may be due to differences in sample size, variations in equipment performance, procedure protocol, and operator skill. The higher dose values in this study indicate the need for optimization of patient doses [6].

Table 11. DRLs for pediatric CT examination compared to NDRL and other international studies.

Procedure	Age	This study		NDRL[18]		EC [9]	
		$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP	$CTDI_{vol}$	DLP
CT head	0-4 years	25	449	64	1430	-	-
	5-14 years	48	884	61	1391	-	600
CT chest	0-4 years	3.7	85	-	-	-	-
	5-14 years	12	526	14	443	-	-
CT abdomen	0-4 years	12	208	15	356	-	-
	5-14 years	31	908	18	744	-	-

Table 12 shows the DRL for adult - Interventional Radiography (IR) compared to the IAEA study [26]. The DRL values of adult in interventional radiography (IR) in this study for Percutaneous Coronary Intervention (PCI) and Coronary Angiography are lower compared to the IAEA study. This indicates that optimization has been done in interventional radiography (IR) for both of the examination.

Table 12. DRLs for Adult - Interventional Radiography (IR) compared to IAEA.

Type of examination	Age	This Study	IAEA [26]
		P_{KA} (Gy.cm^2)	P_{KA} (Gy.cm^2)
Percutaneous Coronary Intervention (PCI)	Adult (≥ 15 years)	101	125
Coronary Angiography (CA)	Adult (≥ 15 years)	96	50
Trans Arterial Chemo Embolization (TACE)	Adult (≥ 15 years)	28	-
Digital Subtraction Angiography (DSA)	Adult (≥ 15 years)	42	-
Arteriography	Adult (≥ 15 years)	32	-
Catheterization	Adult (≥ 15 years)	41	-
Electrophysiology Ablation	Adult (≥ 15 years)	74	-
Endovascular treatment of abdominal aortic aneurysms (EVAR)	Adult (≥ 15 years)	28	-

A DRL is an investigational level used to identify unusually high radiation doses for common diagnostic medical X-ray imaging procedures [26-27]. By investigating the patient's dose, hopefully the cause can be found and the necessary adjustments can be made. If the values of DRL quantities for patients are higher than expected, the investigations should include a review of equipment performance, procedural protocols, operator skills, and complexity of procedures for interventional radiography. The equipment faults or incorrect setup is the easiest to evaluate and make corrections while operator performance is the most difficult aspect to analyze

because it is influenced by the operator's knowledge, skills, and training. Especially when the latest technology is introduced, operators with good skills can raise awareness about dose-saving management. An operator with a lot of experience can help lower the dose a patient receives. Operator training on the dose-saving feature can help achieve patient dose optimization.

Although the dose limit must not be exceeded, DRLs may be exceeded if clinically necessary [1]. Optimization must balance image quality with patient dose while maintaining appropriate image quality when the patient dose is decreased. In clinical practice, we should not only focus on reducing the dose, but also maintaining image quality. In this study, the image quality was at least sufficient for diagnostic purposes. A radiology team consisting of radiologists, radiographers, and medical physicists can find dose reduction strategies without affecting the overall imaging quality of a particular diagnostic examination.

The establishment of DRL is a continuous process carried out by the radiology team (radiologists, medical physicists, radiographers, regulators, etc.). Good cooperation between the regulatory body, health authority, and radiology team could drive this survey more efficient and beneficial to the patients.

This study has limitations in data collection, especially for pediatric radiology patients with a lack of studies and data that can be used in determining DRL, due to the limitations of patients with a certain size. Assigning DRL values for children is more challenging than for adults because of the large number of pediatric patient sizes being investigated. The integration of patient data from various service units/departments can better support data to support this research. The dental panoramic is one of the next projects which will be completed in 2021.

The developed guidelines on justification and optimization principles can assist in the development of the DRL. Operators with good skills can raise awareness about dose-saving management and training on operator's dose-saving features can help achieve patient dosage optimization. The recommendations for the integration of Hospital and Radiology Information Systems are needed to provide data for larger number of patients and the use of electronic transfer of these data to assist the availability of patient examination survey data to support DRL data. The determination of the institutional DRL will be revised periodically (3–5 years). Changes can be made if new imaging technologies or protocols are used.

CONCLUSION

Institutional DRL values at Cipto Mangunkusumo Hospital for general radiography, nuclear medicine, mammography, CT examination, and interventional radiography have been successfully obtained. The established DRL values can be used as a tool for dose optimization, i.e., to create guidelines for good clinical practice in medical imaging, to achieve optimal values for the medical imaging protocol, and to prevent unnecessary patient radiation exposure.

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AUTHOR CONTRIBUTION

T. Amalia and B .Zulkarnaien conceived the idea. K. Nurcahyo, H. Tussyadiah and D. E. Pradana provided data. T. Amalia and C. Anam wrote the paper. All authors approved the final version of the paper.

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