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Tarikh : 25/04/2025

Semua Pengarah Kesihatan Negeri
Semua Pengarah Hospital

Semua Pemegang Lesen Hospital (Perubatan Nuklear)
Di bawah Akta Perlesenan Tenaga Atom 1984 (Akta 304)
Bagi Maksud Perubatan

YBhg. Datuk/Dato'/Datin/Tuan/Puan,

SURAT PEKELILING KETUA PENGARAH KESIHATAN MALAYSIA BIL.15/2025

MALAYSIA NATIONAL DIAGNOSTIC REFERENCE LEVEL (DRL) FOR NUCLEAR MEDICINE 2025

Dengan hormatnya saya merujuk kepada perkara tersebut di atas.

2. Dimaklumkan bahawa Kementerian Kesihatan Malaysia (KKM) telah menyediakan *Malaysia National Diagnostic Reference Level (DRL) for Nuclear Medicine 2025* sebagai satu panduan kepada semua fasiliti perubatan yang menggunakan perkhidmatan perubatan nuklear.

3. Hal ini adalah selaras dengan Peraturan 54 dalam Peraturan-peraturan Perlesenan Tenaga Atom (Perlindungan Sinaran Keselamatan Asas) 2010 di bawah Akta Perlesenan Tenaga Atom 1984 (Akta 304). DRL yang disediakan ini digunakan sebagai panduan supaya:

(a) tindakan pembetulan diambil sebagaimana yang perlu jika dos dan aktiviti jatuh dengan banyaknya di bawah nilai DRL dan dedahan itu tidak memberikan maklumat diagnostik yang berguna dan tidak menghasilkan faedah perubatan yang dijangkakan kepada pesakit; dan

(b) kajian semula dipertimbangkan jika dos dan aktiviti melebihi nilai DRL bagi memastikan perlindungan optimum terhadap pesakit dan mengekalkan aras amalan baik yang sesuai.

..2/-

4. Di samping itu, dokumen ini turut memperkenalkan nilai *achievable dose* untuk diguna pakai bersama nilai DRL kebangsaan. Nilai ini dapat memberikan maklumat tambahan bagi membantu dalam mengoptimumkan kualiti imej dan dos pesakit.

5. Oleh yang demikian, bersama-sama ini dilampirkan pekeliling *Malaysia National Diagnostic Reference Level (DRL) for Nuclear Medicine 2025* untuk rujukan dan panduan.

6. Pekeliling ini adalah berkuatkuasa mulai tarikh surat ini dikeluarkan.

7. Sekiranya terdapat sebarang pertanyaan berkaitan dengan Pekeliling ini, pihak YBhg. Datuk/Dato'/Datin/Tuan/Puan boleh menghubungi Bahagian Kawalselia Radiasi Perubatan, KKM di talian 03-8892 4727 atau emel kepada nurmazaina@moh.gov.my/ najibah.ar@moh.gov.my.

Sekian, terima kasih.

"MALAYSIA MADANI"

"BERKHIDMAT UNTUK NEGARA"

Saya yang menjalankan amanah,

(DATUK DR MUHAMMAD RADZI BIN ABU HASSAN)

MALAYSIA NATIONAL DIAGNOSTIC REFERENCE LEVEL (DRL)

FOR NUCLEAR MEDICINE

2025

Year 2025

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The Committee sincerely thanks all the appointed local coordinators for their valuable contribution to the success of this study. Their dedication in gathering the necessary data efficiently and accurately showed great organizational and leadership skills. We also wish to express our heartfelt thanks to all the healthcare facilities that contributed their data to this important study. Without their collaboration and willingness to share crucial information, the development of the Malaysia National DRL would not have been possible.

The Committee would also like to express our sincere gratitude to all those who contributed at any stage of the research process, from the creation of the research proposal to the finalization of this report.

1. Introduction and Background of Establishment of the Diagnostic Reference Level (DRL)

The International Atomic Energy Agency (IAEA) Safety Standards: General Safety Requirements Part 3 (GSR Part 3) define diagnostic reference level (DRL) as:

"A level used in medical imaging to indicate whether, in routine conditions, the dose to the patient or the amount of radiopharmaceuticals administered in a specified radiological procedure for medical imaging is unusually high or unusually low for that procedure."

The International Commission on Radiological Protection (ICRP) Publication 135 defines a DRL as a form of investigation level used as a tool to aid in optimisation of protection in medical exposure of patients in diagnostic and interventional procedures. It is used in medical imaging with ionising radiation to indicate whether, in routine conditions, the amount of radiation used for a specified procedure is unusually high or low for that procedure.

DRL is a level set for a standard procedure for groups of "standard-sized patients" and not for individual exposures. All individuals who carry out medical radiological procedures should be familiar with the important role of DRL in optimisation. The radiation metric used as a DRL quantity should be easily measured or available and whenever possible, DRL are to be based on clinical tasks.

The concept of DRL is well established and has been widely accepted for many years in the country. Knowledge of trends in medical radiation exposure from the use of diagnostic nuclear medicine and their distribution in the Malaysian population is a useful guide on where best to optimize our efforts to protect the population in a cost-effective manner. It is also needed in reviewing the Malaysian DRL established in 2013, which is recommended as a guide for medical exposure from various examinations, to avoid unnecessary high patient doses.

Presently, the Atomic Energy Licensing Act 1984 (Act 304) regulates the usage of ionising radiation in Malaysia, including in medical applications. All nuclear medicine imaging equipment must undergo annual quality control (QC) tests according to recommendations made by Ministry of Health (MOH). The Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 [P. U. A (46)] (BSRP 2010) made under the Act 304 defines medical exposure as the exposure incurred by:

i. a patient as part of his medical or dental investigative or diagnostic procedures or treatment;

ii. a person who knowingly assists in the support and comfort of patients, other than a person who is occupationally exposed; or

iii. a volunteer in a medical research programme that involves radiation exposure.

Regulations 5, 42(1), 49 (1)(a-b) and 54 of the BSRP 2010 further require the medical institutions to comply with the requirements of medical exposure, namely for nuclear medicine practices, to ensure that:

i. the exposure of patients is at the minimum level required in order to achieve the intended diagnostic objective;

ii. the relevant information from previous examinations is taken into account in order to avoid unnecessary additional examinations.

The main objective of Medical Radiation Exposure Study in Malaysia conducted from 2007 to 2009, was to develop a national database of patient's dose undergoing nuclear medicine studies with the view of establishing Malaysian DRL. The study was carried out under actual clinical settings. The DRL for nuclear medicine were based only on the mean administered activity value of the dose distribution collected in the study. The patients involved were categorised as paediatric (<16 years) and adult (>16 years). Therefore, the first "Guidelines Malaysian Diagnostic Reference Levels (DRLs) in Medical Imaging (Nuclear Medicine)" was published in 2013.

Establishing new DRL is essential to ensure that medical imaging practices remains safe, effective and align with current technological advancement and clinical standards. Therefore, Ministry of Health (MOH) has initiated a review of the current national DRL (NDRL) and population exposure in nuclear medicine services. A National Survey on Medical Radiation Exposure in Nuclear Medicine was conducted between 2022 to 2023 which includes common studies in nuclear medicine services and CT exposure data from hybrid imaging technologies such as Computed Tomography Dose Index Volume ($CTDI_{vol}$) and Dose Length Product (DLP) values. "Report on Medical Radiation Exposure for the Development of Malaysia National Diagnostic Reference Level (DRL) in Diagnostic Radiology, Oral and Maxillofacial Radiology, and Nuclear Medicine," is published in 2025.

2. Objective

The primary objective is to review the Malaysian DRL in 2013 and establish new national DRL value in view of promoting the basis of optimization procedures in nuclear medicine.

The objective of this document is to fulfill the Section 54 of Atomic Energy Licensing (Basic Safety Radiation Protection) Regulations 2010 [P. U. A (46)] (BSRP 2010) to establish and publish the new national DRL in nuclear medicine services.

This document is also to be used as a guidance for the licensee to establish their own facility DRL in accordance with national DRL.

Furthermore, to guide and assist the authority to monitor in the regular dose audit compliance and practices review for promoting improvement in patient protection.

3. Dosimetric Quantities

DRL quantities assess the amount of ionizing radiation used for a medical imaging procedure, not absorbed dose to a patient or organ. DRL quantities should be appropriate to the specific study being performed, and to the specific size of the patient. DRL quantities should also:

i) be appropriate to the imaging modality being evaluated;

ii) assess the amount of ionizing radiation applied to perform a medical imaging task; and

iii) be easily measured or determined.

The dosimetric quantities in this survey were expressed as follows:

i) Administered activity (MBq);
ii) Administered activity per body weight (MBq/kg);
iii) $CTDI_{vol}$ (mGy); and
iv) DLP (mGy.cm)

4. Establishment and Review of National DRL

ICRP Publication 135 defines a national DRL as DRL value set in a country based on data from all or a representative sample of healthcare facilities in that country. A DRL

is defined for a specified clinical imaging task. National DRL values are defined as the 75th percentile (third quartile, Q3) of the distribution of the median values of the appropriate DRL quantity observed at each healthcare facility obtained from national surveys.

There are four steps needed to set a national DRL:

i) The most commonly performed routine diagnostic nuclear medicine studies are identified and a lexicon defined; for each imaging modality, dosimetric quantities are identified, accepted, and measuring method is standardised;

ii) Determined sampling size and select healthcare facilities. In each healthcare facility, dosimetric quantities are recorded following the standardised methods;

iii) The median value of dosimetric quantities from each healthcare facility is statistically analysed for each type of study; and

iv) Finally, for diagnostic nuclear medicine, national DRL value should be set as the 75th percentile of the distribution of median values obtained from each healthcare facility.

A summary on steps in setting national DRL is shown in Figure 1.

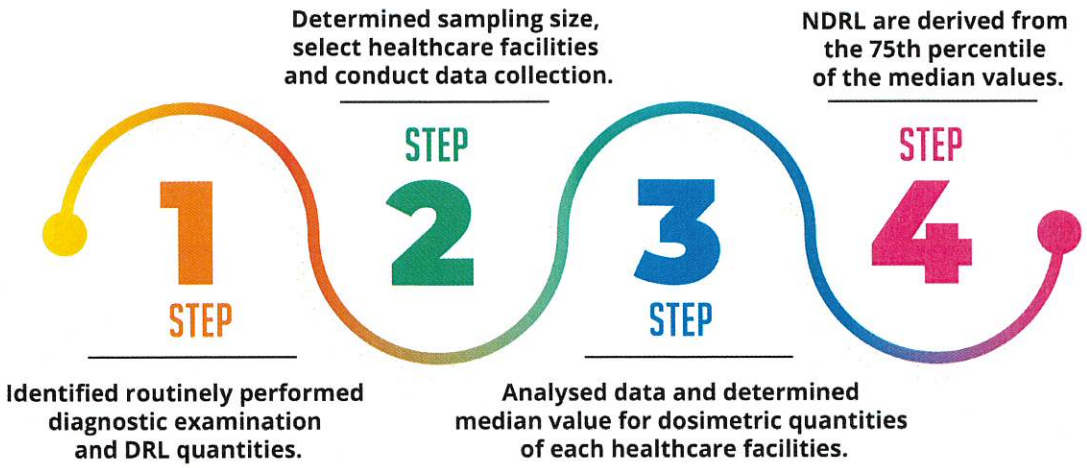

Figure 1: Steps in setting national DRL

Sampling size of healthcare facilities involved in data collection are:

i) Government hospitals;
ii) Private hospitals; and
iii) University hospitals.

5. National DRL (NDRL) 2025

The Committee for the National Survey on Medical Radiation Exposure to Develop Malaysia National Diagnostic Reference Level (DRL) in Nuclear Medicine Services were identified among the qualified and experienced nuclear medicine personnel and appointed by Director General of Health.

The national DRL is developed based on the 75th percentile and the 50th percentile is taken as median value (Table 1 – 4).

DRL values are useful as investigation levels for optimisation of protection in the medical exposure of patients, but they do not provide guidance on what is achievable with optimum performance. Hence, the concept of achievable dose (AD) was introduced and is defined as a level of a DRL quantity 'achievable by standard techniques and technologies in widespread use, without compromising adequate image quality'. This median value of the national distribution can serve as an additional tool to aid in optimisation, may be a desirable goal at which to aim using standard techniques and technologies, and represents a situation closer to the optimum use of the applied radiation.

Important notes: *DRL values shall not be used for individual patients or as trigger (alert or alarm) levels for individual patients or individual examinations. (ICRP 135)*

Table 1: National DRL and achievable dose of the administered radiopharmaceutical activity for adult and paediatric

Types of Studies	Radiopharmaceuticals	Administered activity (MBq)			
		Adult		Paediatric	
		NDRL	Achievable Dose	NDRL	Achievable Dose
SPECT or SPECT/CT					
Bone	Tc-99m MDP	830	768	590	444
	Tc-99m HDP	800	758	340	248
Diagnostic WBS	I-131	200	187	NA	NA

Types of Studies	Radiopharmaceuticals	Administered activity (MBq)			
		Adult		Paediatric	
		NDRL	Achievable Dose	NDRL	Achievable Dose
Thyroid	Tc-99m Pertechnetate	260	197	100	37
Parathyroid (Dual Isotope)	Tc-99m Pertechnetate and Tc-99m MIBI	1060	927	NA	NA
Parathyroid (Single Isotope)	Tc-99m MIBI	910	761	NA	NA
Myocardial Perfusion Study 1 (1-Day Protocol)	Tc-99m Tetrofosmin	300	250	NA	NA
	Tc-99m MIBI	300	206	NA	NA
Myocardial Perfusion Study 2 (1-Day Protocol)	Tc-99m Tetrofosmin	840	742	NA	NA
	Tc-99m MIBI	940	888	NA	NA
Myocardial Perfusion Stress (2-Days Protocol)	Tc-99m Tetrofosmin	500	265	NA	NA
	Tc-99m MIBI	810	740	NA	NA
Myocardial Perfusion Rest (2-Days Protocol)	Tc-99m Tetrofosmin	500	267	NA	NA
	Tc-99m MIBI	810	733	NA	NA
Renal	Tc-99m DTPA	300	250	190	133
	Tc-99m MAG3	200	187	55	49
	Tc-99m DMSA	185	164	80	60
Lung Perfusion	Tc-99m MAA	300	194	NA	NA
Lymphoscintigraphy	Tc-99m Nanocolloid	85	74	NA	NA

Types of Studies	Radiopharmaceuticals	Administered activity (MBq)			
		Adult		Paediatric	
		NDRL	Achievable Dose	NDRL	Achievable Dose
Sentinel Lymphoscintigraphy	Tc-99m Nanocolloid	40	37	NA	NA
	Tc-99m Albumin Colloid	80	79	NA	NA
PET/CT					
Brain	F-18 FDG	260	216	NA	NA
Oncology/ Infection/Vasculitis	F-18 FDG	290	253	190	143
	Ga-68 DOTATATE	220	188	NA	NA
	Ga-68 PSMA	200	181	NA	NA

Table 2: National DRL and achievable dose in administered activity per body weight for adult and paediatric

Types of Studies	Radiopharmaceuticals	Administered activity per body weight (MBq/kg)			
		Adult		Paediatric	
		NDRL	Achievable Dose	NDRL	Achievable Dose
SPECT or SPECT/CT					
Bone	Tc-99m MDP	NA	NA	14.0	12.7
	Tc-99m HDP	NA	NA	15.4	10.1
Thyroid	Tc-99m Pertechnetate	NA	NA	5.9	2.9

Types of Studies	Radiopharmaceuticals	Administered activity per body weight (MBq/kg)			
		Adult		Paediatric	
		NDRL	Achievable Dose	NDRL	Achievable Dose
Renal	Tc-99m DTPA	NA	NA	4.9	4.1
	Tc-99m MAG3	NA	NA	5.5	4.7
	Tc-99m DMSA	NA	NA	4.8	4.4
PET/CT					
Oncology/ Infection/Vasculitis	F-18 FDG	4.7	4.1	4.6	4.1

Table 3: National DRL and achievable dose for $CTDI_{vol}$ for hybrid CT of SPECT/CT and PET/CT in adult and paediatric

Types of Studies	Body Region	$CTDI_{vol}$ (mGy)			
		Adult		Paediatric	
		NDRL	Achievable Dose	NDRL	Achievable Dose
SPECT/CT					
Bone	Whole body	5.3	4.0	NA	NA
	Head and Neck	4.0	4.0	NA	NA
	Thorax	3.5	3.0	NA	NA
	Abdomen/pelvis	3.0	3.0	NA	NA
Diagnostic WBS	Neck	6.0	4.7	NA	NA

Types of Studies	Body Region	$CTDI_{vol}$ (mGy)			
		Adult		Paediatric	
		NDRL	Achievable Dose	NDRL	Achievable Dose
Thyroid	Neck	12.9	7.4	NA	NA
Parathyroid	Neck/Thorax	13.1	7.5	NA	NA
Cardiac	Thorax	2.0	2.0	NA	NA
Lung Perfusion	Thorax	6.0	6.0	NA	NA
PET/CT					
Brain	Brain	44.0	44.0	NA	NA
Oncology/ Infection/ Vasculitis	Whole body	10.3	6.8	6.7	4.1

Table 4: National DRL and achievable dose for DLP for hybrid CT of SPECT/CT and PET/CT in adult and paediatric

Types of Studies	Body Region	DLP (mGy.cm)			
		Adult		Paediatric	
		NDRL	Achievable Dose	NDRL	Achievable Dose
SPECT/CT					
Bone	Whole body	324	261	NA	NA
	Head and Neck	180	180	NA	NA

Types of Studies	Body Region	DLP (mGy.cm)			
		Adult		Paediatric	
		NDRL	Achievable Dose	NDRL	Achievable Dose
	Thorax	166	125	NA	NA
	Abdomen/pelvis	125	125	NA	NA
Diagnostic WBS	Neck	281	181	NA	NA
Thyroid	Neck	407	239	NA	NA
Parathyroid	Neck/Thorax	426	325	NA	NA
Cardiac	Thorax	69	37	NA	NA
Lung Perfusion	Thorax	281	281	NA	NA
PET/CT					
Brain	Brain	944	938	NA	NA
Oncology/ Infection/ Vasculitis	Whole body	1076	737	974	585

6. Local DRL (LDRL)

Local DRL is tailored to the practices, equipment, and patient population of a specific institution or locality. It can be developed for situations such as:

i. National DRL is not available for the identified procedures; or
ii. National DRL is available but local equipment or techniques have enabled a greater degree of optimisation.

National DRL for nuclear medicine study is based on the 75th percentile value of the distribution of the dosimetric quantities with a minimum sample size of 30 per study for adult and 20 per study for paediatric from the healthcare facilities. The establishment of local DRL shall follow similar methods as establishment of national DRL shown in Figure 1.

7. Facility DRL (FDRL)

Facility DRL refers to typical values in ICRP 135 and establish by the median of the distribution of the data for a DRL quantity for a clinical imaging procedure. Facility DRL is a basis to form local DRL.

7.1 Establishment of facility DRL

Establishing facility DRL is the first step in the cyclical DRL process or audit cycle. Then process for establishing facility DRL is detailed in Figure 2.

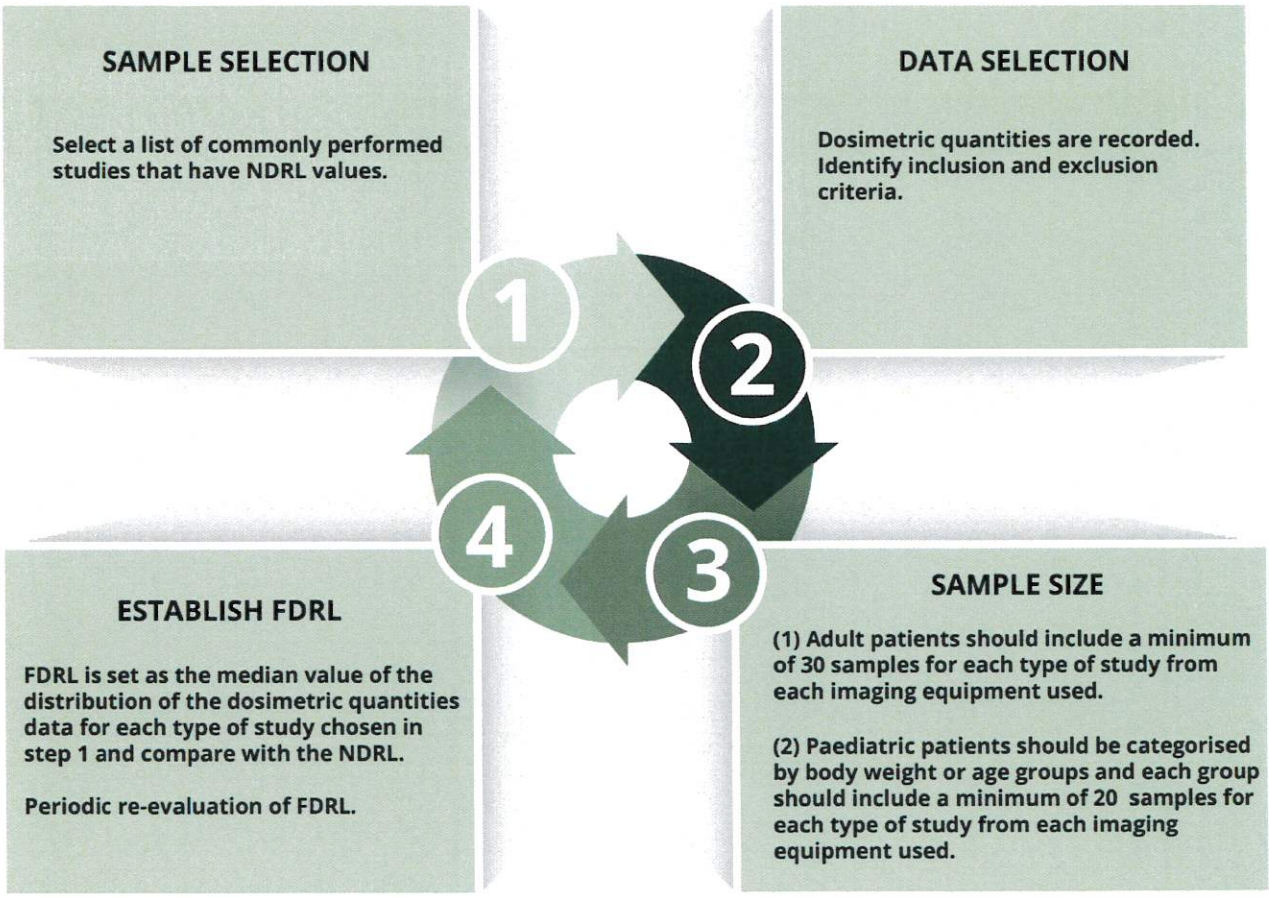

Figure 2: The process for establishing FDRL

Facility DRL need to be established, regularly reviewed and used, taking corrective action where necessary. If facility DRL exceed or are substantially lower than national DRL values, an investigation must be conducted by the nuclear medicine team to ensure optimal practices and intended outcomes are delivered. Both national DRL and facility DRL are to be reviewed when new technologies are introduced, or a procedure is changed to ensure that there is adequate optimisation to protect the patients.

7.2 Application of facility DRL

Facility DRL serve as a benchmark for evaluating the radiation dose administered during diagnostic procedures within a specific facility. The first step in using facility DRL is comparison with the national DRL value. If this does not exist for a particular procedure or clinical task, local DRL or similar internationally established DRL values or peer reviewed literature can be consulted.

If facility DRL consistently exceed or are lower than national DRL or local DRL values, an investigation must be conducted to ensure optimal practices and intended outcomes are delivered. Healthcare facilities are required to retain records of DRL reviews, and any corrective actions carried out for a period of times and make these records available during regulatory audit.

All healthcare personnel involved should be familiar with the important role of DRL in optimisation of nuclear medicine studies for the protection and safety of patients. The concept and proper use of DRL should be included in the education and training programmes.

Facility DRL should never be applied to individual patients, as some patients will require higher amounts of radiation for a given imaging examination or procedure than others due to their size, a particular diagnosis, or the complexity of the procedure. It is important to note that DRL should be used as a supplement to professional judgement to aid in the optimisation of medical exposures to ionising radiation.

7.3 Review of facility DRL

The review process does not stop after a single assessment. Repeat surveys will be required following any optimisation, and the whole process should be repeated after an appropriate time interval.

If values of $CTDI_{vol}$ or DLP for the CT component of hybrid imaging (i.e. PET/CT and SPECT/CT) are above the DRL value, the purpose of the imaging task (i.e. whether it is primarily a diagnostic test or performed for attenuation correction or positioning) should be considered. Reviews of DRL quantities should be done periodically.

Figure 3 illustrates the workflow involved in the audit cycle and optimisation process, outlining the key stages from initial data collection through to the implementation of improvements.

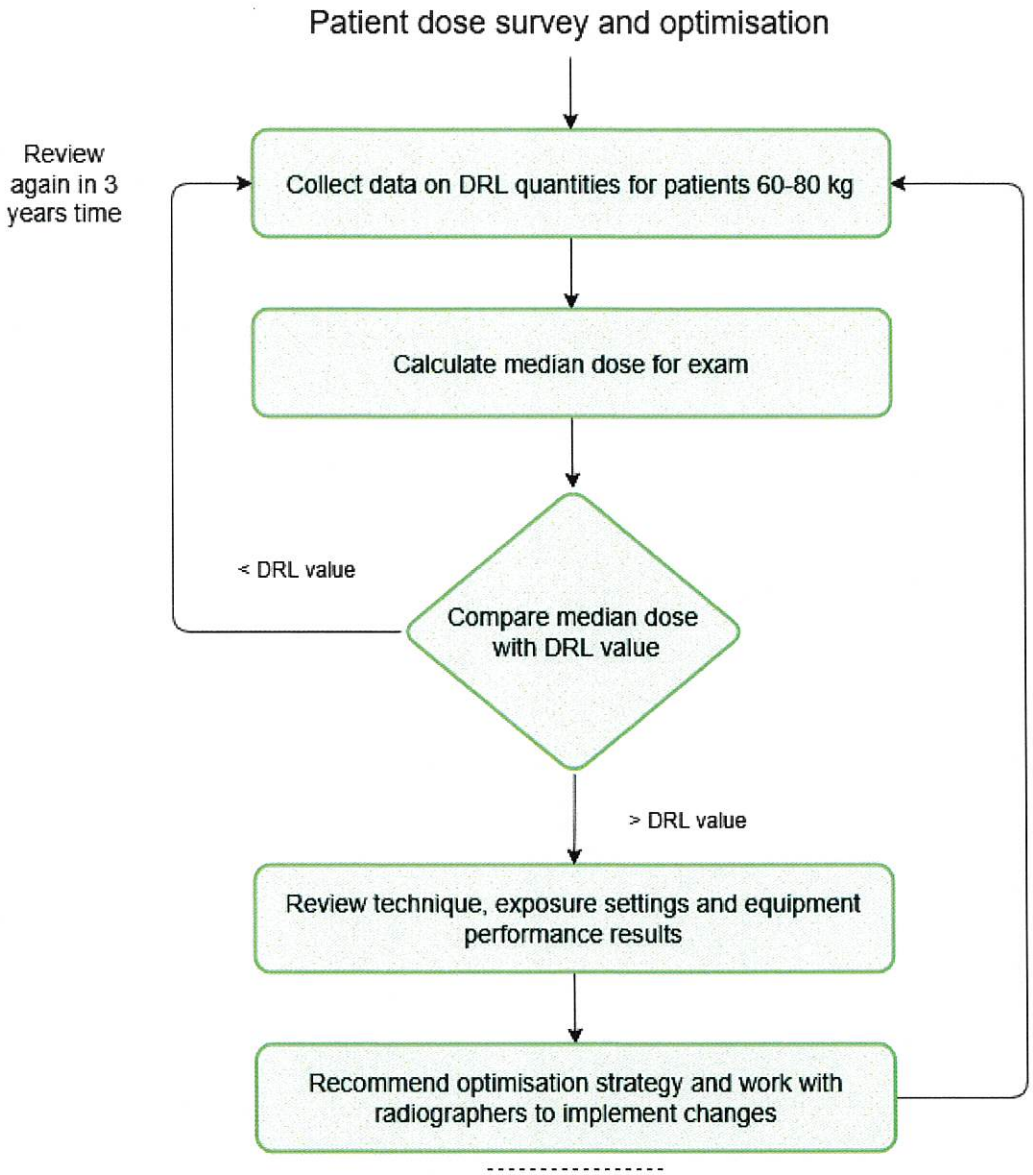

Figure 3: Workflow for audit cycle and optimization process

7.4 Corrective action for facility DRL

An investigation of equipment and practices must be conducted immediately and corrective actions taken if facility DRL consistently exceeds the national DRL or local DRL. Corrective action based on optimisation of protection should include a review of equipment performance, the settings used, and the study protocols. The factors most

likely to be involved are survey methodology, equipment performance, procedure protocol, operator skill, and procedure complexity.

When facility DRL value is substantially below the achievable dose, image quality might be affected adversely. Image quality should be prioritised when the study protocol is reviewed.

Meanwhile, Figure 4 presents the decision tree developed to guide corrective actions for the facility DRL. This structured approach helps users systematically identify the necessary actions when comparing facility DRL to national DRL and select the appropriate steps.

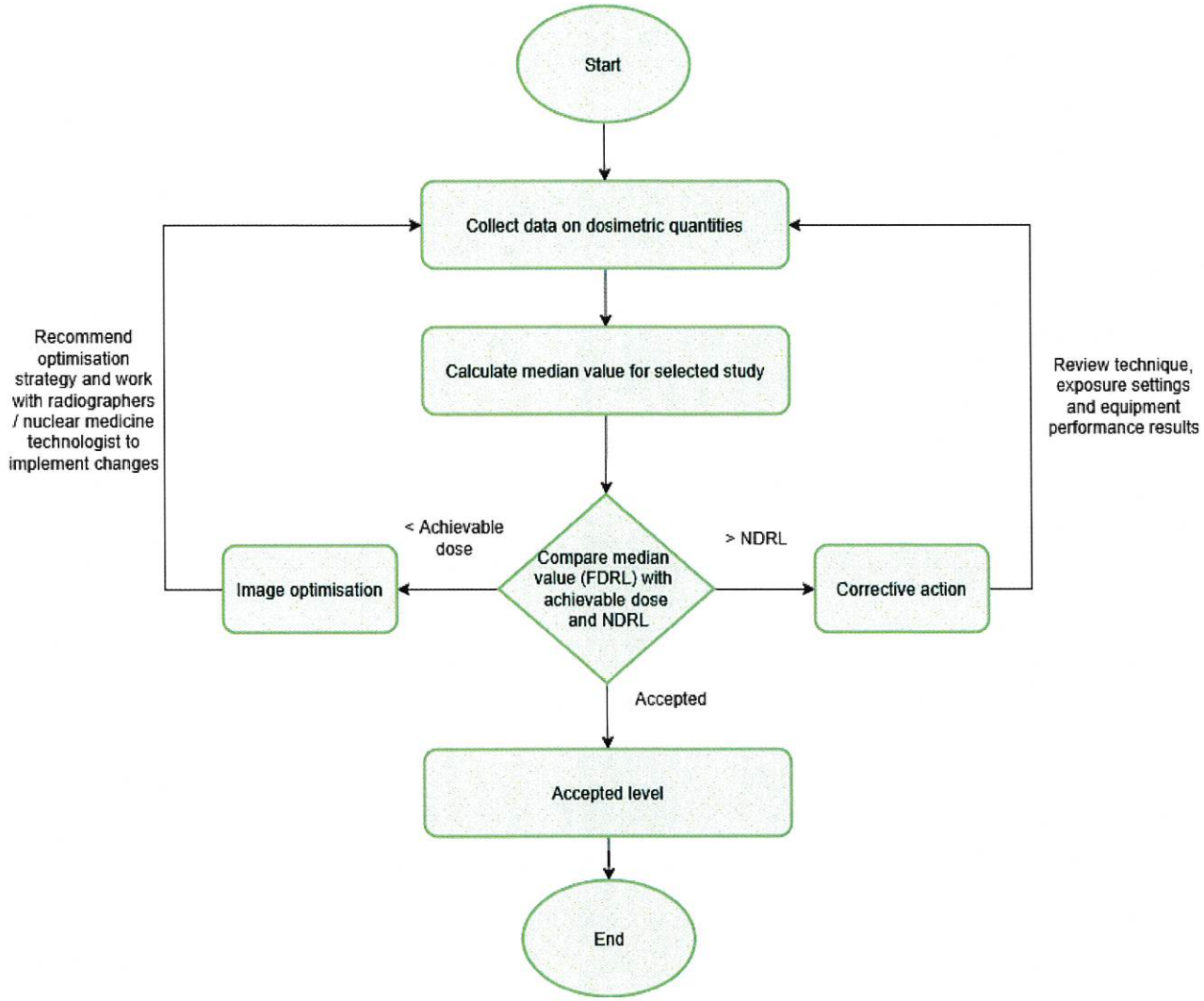

Figure 4: Workflow of corrective action by the facility

8. Recommendation

The current survey identified several limitations with recommendations being suggested.

i. Demographic information

   a. The survey lacks comprehensive demographic data such as gender, body weight, height, and BMI categories.

   b. Future surveys should clearly define and record these details for better analysis.

ii. Paediatric data collection

   a. Age and weight categorization for paediatric groups was applied, but data collection was insufficient for detailed analysis.

   b. Future studies should examine paediatric patients weighing more than 70 kg using adult protocols.

   c. Extending the study period and increasing the minimum sample size for paediatric populations is recommended.

   d. Guidelines from organizations like ICRP and the European Commission suggest incorporating age, height, and clinical context into paediatric DRL.

iii. Clinical context

   a. The survey did not include clinical context, which is critical for informed decision-making and consistent protocols.

   b. Future studies should integrate clinical context for better relevance and accuracy.

iv. Technological developments

   a. The survey did not account for the age of imaging equipment or advancements in technology.

   b. Modern technologies (e.g., semiconductor cameras, time-of-flight, point spread function in SPECT/CT or PET/CT, and CT techniques like automatic tube current modulation) can reduce radiation exposure while maintaining image quality.

c. A national strategy for equipment replacement and technology adoption should be considered.

v. Administered activity and image quality

a. Administered activity was evaluated using fixed doses without optimizing visual and quantitative image quality.

b. Future evaluations should balance activity with image quality to achieve optimal outcomes and ensure safety.

vi. Radiopharmaceutical activity and protocols

a. Radiopharmaceutical activity varies with scanning sequences and protocols, which were not clearly clarified in the survey.

b. Clearly defined protocols are necessary for studies like lung perfusion and sentinel lymphoscintigraphy to ensure consistency and accuracy.

c. Radiopharmaceutical activity and CT values in parathyroid studies were higher compared to other countries. Healthcare facilities should review and optimize their imaging protocols to improve practices.

vii. CT parameters in hybrid imaging

a. Significant variability in $CTDI_{vol}$ and DLP values was observed, influenced by technology, protocols, and clinical indications.

b. Future surveys should document these details along with additional body regions and parameters like kV and mAs.

c. Training and upskilling of nuclear medicine personnel should be prioritized to ensure proficiency in advanced technologies.

viii. Facility DRL

a. Encourage healthcare facilities to develop and maintain their own facility DRL, enabling benchmarking and alignment with local or national standards.

b. Continuous recording and analysis of patient dose data for ongoing optimization.

ix. Local DRL

Encourage establishment of local DRL where no national DRL is available and use them as a tool for optimisation. Local DRL can also be establish if there is a national DRL value but local 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.

x. Collaboration among stakeholders

a. Establish multidisciplinary teams comprising nuclear medicine physicians, medical physicists, pharmacists and nuclear medicine technologists to drive DRL development and implementation.

b. Promote clear communication and collaboration across facilities to unify practices.

xi. Education and Awareness

a. Enhance training and education programs for radiation workers to ensure a deeper understanding of DRL and clinical dosimetry.

b. Raise awareness about balancing radiation exposure with diagnostic image quality to prioritize patient safety.

9. Conclusion

National DRL values are set for common nuclear medicine studies in Malaysia. These allow licensees to compare their facility DRL, representative of patient dose, to the national DRL. Where facility DRL are deemed too high or too low, an immediate investigation into the cause is required. Corrective actions identified must be recorded. Licensees shall ensure that healthcare professionals and individuals that conduct medical exposures are informed of national DRL and facility DRL to facilitate patient dose optimisation.

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Appendix 1: Glossary of Terms

Achievable dose (AD)
A dose that serves as a goal for optimisation efforts. This dose is achievable by standard techniques and technologies in widespread use, while maintaining clinical image quality adequate for diagnostic purposes. The achievable dose is set at the median value of the dose distribution.

Computed tomography dose index (volume) ($CTDI_{vol}$)
The weighted CTDI, $CTDI_w$, normalised by the helical pitch. $CTDI_w$ is an estimate of the average dose over a single slice in a CT dosimetry phantom, measured in mGy.

Diagnostic reference level (DRL)
A diagnostic reference level is a form of investigation level used as a tool to aid in optimisation of protection in the medical exposure of patients for diagnostic and interventional procedures. It is used in medical imaging with ionising 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 administered activity (amount of radioactive material), or preferably the administered activity per unit of body weight, is used.

Dose-length product (DLP)
A parameter used as a surrogate measure for energy imparted to the patient in a computed tomography scan of length L. The DLP unit is mGy.cm.

DRL process
A cyclical process of establishing DRL values, using them as a tool for optimisation, and subsequently determining updated DRL values as a tool for further optimisation.

DRL quantity
A commonly and easily measured or determined radiation metric (e.g. $CTDI_{vol}$, DLP, and administered activity) that assesses the amount of ionising radiation used to perform a medical imaging task. The quantity or quantities selected are those that are readily available for each type of medical imaging modality and medical imaging task.

Facility DRL (FDRL)

The median of the distribution of the data for a DRL quantity for a clinical imaging procedure. The distribution includes data collected from a particular healthcare facility that has several x-ray rooms.

Facility DRL can be used:

i. as a guide to encourage further optimisation in a facility by providing a facility comparator, in a similar manner to national DRL or local DRL; or
ii. for a single facility to provide a comparator linked to a new technology or technique.

Local DRL (LDRL)

A DRL for an x-ray procedure set within a few healthcare facilities in Malaysia for a defined clinical imaging task, based on the 75th percentile value of the distribution of the appropriate DRL quantity in a reasonable number (e.g.10–20) of x-ray rooms in a local area. Local DRL may be set for procedures for which no national DRL is available, or where there is a national value but local equipment or techniques have enabled a greater degree of optimisation to be achieved so that a value less than the corresponding national DRL can be implemented.

Medical exposure

Radiation exposure incurred:

i. by patients as part of their own medical or dental diagnosis or treatment;
ii. by persons, other than those occupationally exposed, knowingly, while voluntarily helping in the support and comfort of patients; or
iii. by volunteers in a programme of biomedical research involving their exposure.

National DRL (NDRL)

DRL value set in Malaysia based on data from a representative sample of healthcare facilities. A DRL is defined for a specified clinical imaging task. National DRL values are usually defined as the third quartile (75th percentile) of the distribution of the median values of the appropriate DRL quantity observed at each healthcare facility.

Appendix 2: List of Committee Member

The Committee for the Study of Medical Radiation Exposure to Develop Malaysia National Diagnostic Reference Level (DRL) in Nuclear Medicine Services

1.	Dr. Siti Zarina binti Amir Hassan Head of National Nuclear Medicine Expertise KKM (Chairman)	Hospital Kuala Lumpur
2.	Dr. Zunaide bin Kayun@Farni Former Director	Bahagian Kawalselia Radiasi Perubatan
3.	En. Bazli bin Sapiin Director	Bahagian Kawalselia Radiasi Perubatan
4.	Pn. Nurmazaina binti Md Ariffin Principal Assistant Director (Principal Investigator)	Bahagian Kawalselia Radiasi Perubatan
5.	Dr. Nor Salita binti Ali Nuclear Medicine Specialist	Institut Kanser Negara
6.	Dr. Fadzilah binti Hamzah Nuclear Medicine Specialist	Hospital Pulau Pinang
7.	Dr. Ng Chen Siew Nuclear Medicine Specialist (Investigator)	Hospital Sultanah Aminah
8.	Prof. Dr. Subapriya a/p Suppiah Nuclear Medicine Specialist (Investigator)	Hospital Sultan Abdul Aziz Shah, UPM
9.	Dr. Tan Teik Hin Nuclear Medicine Specialist	Sunway Medical Centre Sdn. Bhd. (Perubatan Nuklear)
10.	Pn. Noor Diana binti Dolmat Medical Physicist (Investigator)	Hospital Kuala Lumpur
11.	Pn. Dhalisa binti Hussin Medical Physicist (Investigator)	Hospital Sultanah Aminah
12.	Dr. Fatin Nadhirah binti A. Halim Medical Physicist (Investigator)	Hospital Pulau Pinang
13.	Prof. Madya Dr. Noramaliza binti Mohd Noor Medical Physicist (Investigator)	Hospital Sultan Abdul Aziz Shah, UPM

14.	Ts. Azleen binti Mohd Zain Medical Physicist	Pusat Perubatan Universiti Malaya
15.	Pn. Maimanah binti Muhamad Medical Physicist	Pusat Perubatan Universiti Kebangsaan Malaysia
16.	Pn. Kala Krishnan a/p Mohandas Medical Physicist	Beacon Hospital Sdn. Bhd. (Perubatan Nuklear)
17.	En. Mohd Borhanuddin bin Md Hassan Nuclear Pharmacist	Hospital Kuala Lumpur
18.	Dr. Zaitulhusna binti Md Safee Nuclear Pharmacist	Institut Kanser Negara
19.	En. Mohamad Taufik bin Yusof Nuclear Pharmacist	Hospital Pulau Pinang
20.	En. Nishaan R.D Sevanesan Nuclear Pharmacist	Beacon Hospital Sdn. Bhd. (Perubatan Nuklear)
21.	Pn. Farhan binti Yusof Radiographer	Sunway Medical Centre Sdn. Bhd. (Perubatan Nuklear)
22.	Pn. Noaidawati binti Embong Medical Laboratory Technologist	Institut Kanser Negara
23.	En. Abu Kassim bin Ali Medical Laboratory Technologist	Pantai Hospital Kuala Lumpur (Perubatan Nuklear)

Secretariat

1.	Pn. Nurmazaina binti Md Ariffin Senior Principal Assistant Director (Principal Investigator)	Bahagian Kawalselia Radiasi Perubatan
2.	Dr. Tan Hun Yee Senior Assistant Director (Investigator)	Bahagian Kawalselia Radiasi Perubatan
3.	Pn. Nur Ashmira binti Aznan Senior Assistant Director (Investigator)	Bahagian Kawalselia Radiasi Perubatan
4.	Pn. Najibah binti Abdul Rahman Senior Assistant Director (Investigator)	Bahagian Kawalselia Radiasi Perubatan

Statistical Advisor

1.	Professor Dr Karuthan A/L Chinna Statistical Advisor	Faculty of Business and Management, UCSI University

Team for Development of DRL Web Application

1.	Ts. Dr. Adi Izhar bin Che Ani	UiTM Cawangan Pulau Pinang
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3.	Ir. Ts. Dr. Samsul bin Setumim	UiTM Cawangan Pulau Pinang
4.	En. Mohd Ikmal Fitri bin Maruzuki	UiTM Cawangan Pulau Pinang
5.	Ir. Dr. Mohd Firdaus bin Abdullah	UiTM Cawangan Pulau Pinang
6.	Dr. Siti Juliana binti Abu Bakar	UiTM Cawangan Pulau Pinang