Diagnostic Reference Levels (DRLs) for SPECT Examinations at the Nuclear Medicine Installation of the RSUD A.W. Sjahranie Samarinda

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Abstract – *Diagnostic reference Level (DRL) is an investigational tool used to help optimize patient protection during diagnostic and interventional procedures in nuclear medicine, the administered activity is based on the patient's body weight. This study aims to determine the diagnostic reference levels (DRLs) for SPECT Examinations: Bone Scan using radiopharmaceutical ^{99m}Tc MDP, Whole Body Scan using radiopharmaceutical ^{99m}Tc MIBI, and Thyroid Whole-Body Scan using radiopharmaceutical ^{131}I. This study included patient aged 15 to 60 years with body weight ranging 35 to100 kg. The DRL was calculated based on the 75th percentile and the results were compared with the BAPETEN DRL and previous research. Finding. The DRLs determined for RSUD AWS Samarinda were 999MBq for Bone Scan examination using ^{99m}Tc MDP, 921.3 MBq for Whole Body Scan using ^{99m}Tc MIBI and 3145 MBq for Thyroid Whole-Body Scan. Based on results, the DRL of Bone Scan and Thyroid WBS exceed the BAPETEN DRL while the DRL for Whole Body Scan using 99TC-MIBI is below the BAPETEN DRL.*

Key words: *Bone Scan; Diagnostic Reference Level (DRL); SPECT; Thyroid WBS; WBS*

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1. Introduction

Ionizing radiation is widely used in society, especially in scientific research as well as the medical field. Numerous studies were developed that aimed to asses the consequences and the associated risks of using this technology, so the International Commission on Radiological Protection (ICRP) introduced justification requirements for the use of radiation in patients since 1955 [1].

Imaging procedures have evolved to enhance diagnostic accuracy and resolve clinical dilemmas. This growth includes the use of anatomical modalities, radiological and the use of functional nuclear medicine modalities, including conventional and hybrid procedures such as Single Photon Emission Computed Tomography/Computed Tomography (SPECT/CT) and Positron Emission Tomography/Computed Tomography (PET/CT). SPECT is a widely used tool in nuclear medicine for imaging many organs including the skeleton, heart, lungs, kidneys, and brain, as well as for whole-body imaging. SPECT studies are typically displayed as a set of slices cut in the trans axial, sagittal, and coronal planes, with an optional three-dimensional interactive display. Compared to 2 dimensional (2D) images, SPECT imaging provides higher contrast, deeper information, and optional quantification [2].

Nuclear medicine is the medical discipline that involves the use of unsealed radioactive sources to diagnose and treat disease. Technological breakthroughs in diagnostics have resulted in the fast expansion of both traditional and novel imaging techniques such as SPECT and PET. Consequently, radiopharmaceuticals are being utilized more often, increasing the workload at the Radiopharmaceutical Unit and Nuclear Medicine Department. Innovative therapeutic methods utilizing open radionuclides are gaining traction. Due to high activity often required to achieve therapeutic benefits, pure beta-gamma radionuclides or beta-gamma combinations are particularly well suited for therapeutic purposes [3].

Nuclear Medicine treatment administering a small dose of radioactive material to the patient and then detecting the location with a gamma camera. Several radiotracers can be given to patients via injection, inhalation, or ingestion. commonly used Radiotracers include ^{111}In, ^{99m}Tc, ^{67}Ga, and ^{18}F. These materials emit gamma radiation, which imaging devices use to determine specific bodily functions. Depending on the radiotracer used, the radioactive material will be eliminated from the patient's body within a few hours to a few days via the lungs, urine, or feces. Unlike other imaging studies, nuclear medicine is able to display the organ function and anatomical structure of the body. It can also display cellular and molecular processes, such as blood flow, cell metabolism, the expression of cell receptors, and more [4]. A radiopharmaceutical that is distributed in accordance with particular physiological or functional pathways is given to the patient in nuclear medicine. The patient is then scanned using an external radiation detector to determine the distribution and dynamics of the radiopharmaceutical in the body, which allows for inference of the patient's physiological condition, providing doctors with important information to aid in diagnosis, prognosis, staging, and treatment. Radiopharmaceuticals are generally administered to patients via intravenous injection, although in some cases they can also be administered via other injection routes, such as intra-arterial, intraperitoneal, or subdermal. In some other cases, the radiopharmaceutical may be administered through the gastrointestinal tract or through the breathing of radioactive gas or aerosol. After administration, the pathway and rate of uptake of the radiopharmaceutical will depend on the type of radiopharmaceutical itself, the route of administration, and the individual physiology of the patient. However, the characteristics and parameters associated with the distribution and dynamics of the radiopharmaceutical in the body are of immense clinical importance [5].

In SPECT imaging, there are many physical factors that can affect the trajectory and detection of a photon, potentially reducing image quality. These phenomena include photon interactions with the human body and interactions with the collimator and detector system. A gamma photon can interact with matter in three main ways: photoelectric effects (PE), scattering, and pair production. For the energies of gamma photons used in SPECT imaging, the dominating interaction is the Compton scatter [6]. In Compton scattering, an incoming photon interacts with an electron, giving part of the photon's energy to the electron and causing the photon to lose energy and shift direction. The kinetic energy of the Compton scattering photon represents the lost energy. In contrast to the photoelectric effect, there is no observable preference for tightly bound electrons; hence, the majority of inter-Compton activity includes outer shell, loosely bound electrons. Electrons are often considered free. Thus, the likelihood of Compton interactions is determined mostly by electron density (electrons per milliliter) rather than electron energy [5]. When just a fraction of the incident photon is passed to the electron, which is emitted at an angle of 4 relative to the incident photon, Compton scattering occurs. At 26 keV-24 MeV, this interaction exhibits a dominating interaction [7].

When an incoming photon interacts with the nuclear field and is entirely absorbed, pair formation happens. Above 10 MeV, this interaction exhibits a dominating interaction. By forming electron-positron couples, some of the energy is transformed into matter. the kinetic energy of the electron and positron is the total energy of the photon minus by the rest energy of electron of positron. The positron is antimatter, and as it slows down while going through matter, it interacts with the electron to generate two photons, each having an energy of 0.511 MeV. Because the electron and positron have resting energies of 0.511 MeV each, pair formation cannot occur until the incoming photon has at least 1.022 MeV of energy [7].

SPECT uses gamma-emitting radioisotopes to measure blood flow and radioisotope distribution throughout tissues and organs to detect strokes, seizures, bone disorders, and infections. The radioisotopes ^{131}I and ^{99m}Tc are commonly used radiopharmaceuticals for SPECT imaging [8]. Since ^{99m}Tc possesses physical and chemical qualities that are perfect for imaging with a gamma camera, so 99mTc is the most often used radionuclide for diagnostic imaging. ^{99m}Tc produces gamma-rays with an energy of 140 keV and a half-life of 6 hours, easily to be labeled with numerous substances, and is reasonably easy to acquire when compared to radionuclides [9, 10].

Iodine-131 (^{131}I) was the first radiopharmaceutical of importance in clinical nuclear medicine. It destroys cancer cells due to its beta emission. The main gamma emission of ^{131}I is a high-energy 364 keV photon, which causes radiation exposure concerns to the public [11, 12]. Iodine-131 is a therapeutically valuable radioactive isotope with an 8.06-day half-life and low beta gamma emissions. The unstable nucleus of ^{131}I develops stability as a beta emitter by turning excess neutrons into protons and generating beta particles. The ^{131}I nucleus is converted to ^{131}Xe via beta-minus decay. ^{131}I is the parent of ^{131}Xe. ^{131}I emits beta particles with energies ranging from 0.81 MeV to 0.18 MeV on average [13].

Radiation-based diagnosis and treatment are only acceptable if the benefits outweigh the risk radiation exposure (justification), and precautions must be taken to limit radiation dose as low as reasonably achievable (ALARA) (optimization). With the improvement of radiation imaging and computer technologies, reference doses for each imaging modality were developed, and these reference doses have come to be known as Diagnostic Reference Levels (DRLs) [14]. Diagnostic Reference Level (DRL) is an effective tool to optimize radiation protection for patient in medical exposure, especially since dose limits do not apply to medical exposures. DRL quantities should evaluate the amount of ionizing radiation used to perform diagnostic, interventional, or nuclear medicine procedures and assess the effective dose to the patient [15].

Research in South Korea highlights the need for optimization of radiation protection during nuclear medicine imaging studies. However, a DRL has yet to be established for these studies in Korea. The recommended initial DRL is the 75th percentile (Q3) based on expert discussion and statistical analysis [16]. Research was carried out at the Nuclear Medicine Department of Cancerology Institute of Libreville out using SPECT/CT equipment and adult patients, with a focus on ^{99m}Tc bone scan examination and the 75th percentile was calculated to obtain local DRL values. Based on the result of this research, the DRL value for Gabon is lower than the DRL value from Kuwait, Nigeria and Australia but higher than the DRL value for United Kingdom [17].

Another study regarding the DRL for Nuclear Medicine in Qatar has reported that the 75th percentile value also known as the third quartile is considered as the initial DRL value and consistent with activities that are often carried out in clinical practice. For each nuclear medicine examination, at the 75th percentile (Q3 third quartile) of the administered activity is calculated and the results are compared to other countries including Kuwait, Korea, Japan, Australia, United Kingdom, United States of America, and other countries [18].

Therefore, we conducted research on Diagnostic Reference Level (DRL) at RSUD AWS, East Kalimantan, Samarinda. This is because the calculation of the DRL value has not been carried out at the hospital. The results of the DRL value calculation will be compared with the DRL value from BAPETEN and also compared with DRL values from other countries such as Thailand, Korea and Kuwait.

2. Method

This study was aimed to establish the DRL for few SPECT examinations at the Nuclear Medicine Installation of the RSUD AWS Samarinda, East Kalimantan. The data taken in this study are the administered activity distribution data, i.e. ^{99m}Tc MDP with the type of Bone Scan examination, ^{99m}Tc MIBI with the type of WBS examination, and ^{131}I with the type of Thyroid WBS examination. the data of this study are the data of male and female adult patients, with age range from 15 to 60 years old and the body weight were about 35 to 100 kg. They were secondary data taken from 2018 to 2022 for bone scan examination data used ^{99m}Tc MDP radiopharmaceutical and WBS examination data used ^{99m}Tc MIBI radiopharmaceutical. The Thyroid WBS examination data used ^{131}I Radiopharmaceutical were data taken from 2019 to 2022. The amount of data on Bone scan used ^{99m}Tc MDP radiopharmaceutical is 3041 patients, on WBS with ^{99m}Tc MIBI radiopharmaceutical was 1803 patients, and on Thyroid WBS used ^{131}I Radiopharmaceutical was 868 patients. The DRL calculated based on the 75th percentile (Q3).

The first step in this study was to collect data provided by medical physicists at the Nuclear Medicine Installation with information of gender, weight (kg), age (years), type of examination, type of radionuclides, radiopharmaceuticals, entry routes, and administered radionuclide activity (MBq). Then, the data was grouped based on the type of examination performed on the patient. After that, the DRL was calculated based on the 75th percentile (Q3) of the distribution of patient dose data for patient examination types such as Bone Scan using ^{99m}Tc MDP, WBS using ^{99m}Tc MIBI, and Thyroid WBS using ^{131}I. DRL was calculated according to Equation (1) to find the 75th percentile (Q3) of the patient dose data distribution [19].

$$Q_3 = 3\left(\frac{n+1}{4}\right) \tag{1}$$

The data distribution is shown in graphs form. Data processing based on the International Commission on Radiological Protection (ICRP) 135 [19] and I-DRL BAPETEN [20].

3. Results And Discussion

According to ICRP 135, the DRL is the 75th percentile (third quartile) of the distribution [21]. The 75th percentile is often much below the high end of the distribution and can be used to identify facilities whose findings are around the top of the distribution. As a result, the International Commission on Radiological Protection (ICRP) establishes and recommends DRL at the 75th percentile of the distribution. Because this technique is practical and easy, DRL for nuclear medicine imaging are set as an administered activity (MBq) or a given activity per body weight (MBq kg^{-1}). The provided activity should be modified in accordance with agreed-upon criteria such as body size or weight. If there is a compelling therapeutic rationale to warrant the modification, the activity allotted to each patient may be increased.

For example, patients who are in extreme pain and cannot tolerate the typical examination duration so that the examination may be completed in a short amount of time, or patients who are fat. Doses less than the DRL value do not imply that the process was carried out at an optimal level in terms of the amount of radiation employed. If the dose is below the DRL, image quality should be a higher priority in the optimization process than the amount of radiation used. The DRL values is surpassed, ICRP 135 suggests to conduct an evaluation or assessment the cause of the DRL value being exceeded [21]. Fig. 1 shows a graph of the Activity distribution on Bone Scan examination using ^{99m}Tc MDP radiopharmaceutical. Fig. 2 show a graph of the Activity distribution on WBS using ^{99m}Tc MIBI radiopharmaceutical. Fig. 3 show a graph of the activity distribution in thyroid WBS using ^{131}I radiopharmaceutical. Fig. 4 show a graph of the Initial activity distribution in thyroid WBS using ^{131}I radiopharmaceutical.

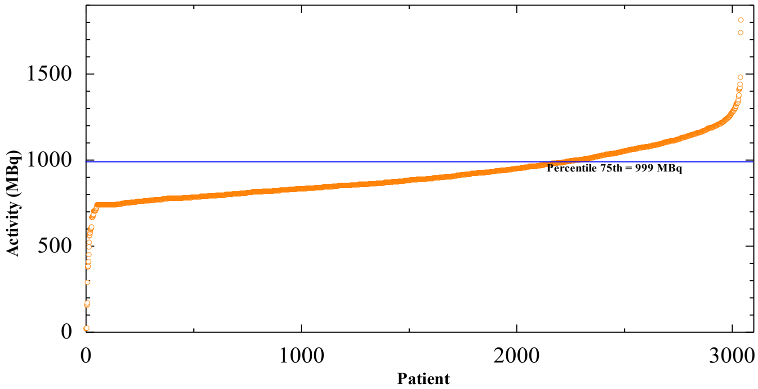

Fig. 1. Activity distribution on Bone Scan examination using ^{99m}Tc MDP radiopharmaceutical.

In the bone scan examination using ^{99m}Tc MDP radiopharmaceutical for 5 years, from 2018 to 2022, there were 3041 patients with different genders, ages, and weights. In Figure 1, the 75th percentile value based on the data processing that has been carried out in this examination is 999 MBq. The 75th percentile value can be used by the DRL of RSUD AWS Samarinda as a reference in determining the DRL value.

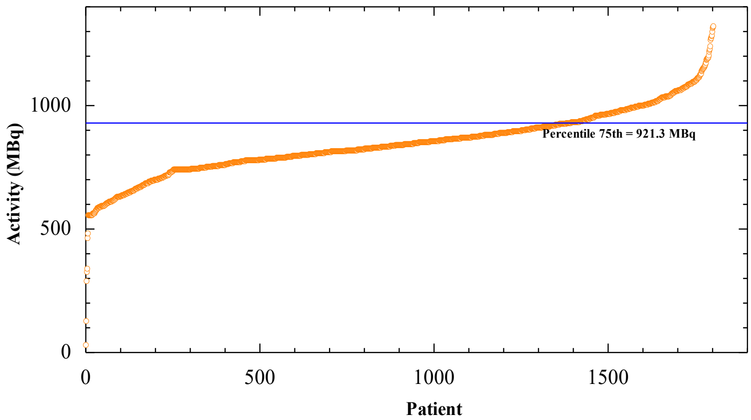

Fig. 2. Activity distribution on WBS using ^{99m}Tc MIBI radiopharmaceutical**.**

WBS data using ^{99m}Tc MIBI radiopharmaceuticals from 2018 to 2022 has a total of 1803 patients. This data is then processed to determine the 75th percentile value, and in Figure 2 the 75th percentile value of the examination at the WBS examination using the ^{99m}Tc MIBI radiopharmaceutical is 921.3 MBq. RSUD AWS can use the 75th percentile value from this data processing as a reference for determining the DRL value.

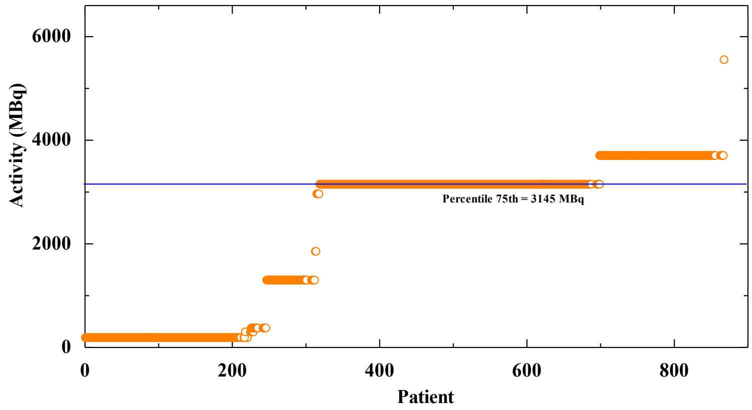

Fig. 3. Activity distribution on Thyroid WBS using ^{131}I radiopharmaceutical**.**

There were 868 patients on the thyroid WBS using ^{131}I radiopharmaceutical from 2019 to 2022. This data is the data that is obtained after the ^{131}I radiopharmaceutical has decayed. Based on data processing in Figure 3, the 75th percentile value is 3145 MBq, and this value can be used as a reference for the DRL value at RSUD AWS Samarinda.

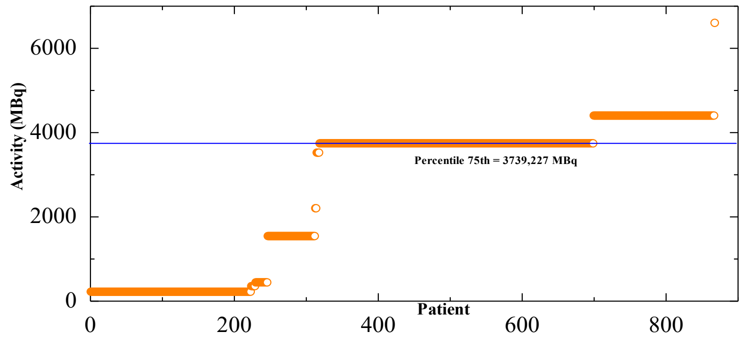

Fig. 4. Initial activity distribution in thyroid WBS using ^{131}I radiopharmaceutical.

Figure 4 shows the 75th percentile value of 3739.227 MBq. The data processed is the initial data of the thyroid WBS examination using ^{131}I radiopharmaceutical from 2019 to 2022 obtained from the ^{131}I decay result data shown in Figure 3. In determining the DRL value, RSUD AWS Samarinda can use the 75th percentile value in this data as a reference.

Based on four figures above, 75% of the data are data of patients who received normal doses and 25% of the data are data of patients who received low and high radiation doses. In the results of data processing, it can be seen that only the DRL from the WBS examination using ^{99m}Tc MIBI is below the DRL from BAPETEN. In the following page, Table 1 shows the DRL of BAPETEN, RSUD AWS Samarinda, and DRL from other countries such as Thailand [22], Korea [16], and Kuwait [15].

Table 1. DRL of BAPETEN, RSUD AWS Samarinda, and DRL from other countries such as Thailand, Korea, and Kuwait.

Examination	Radiopharma-ceutical	DRL RSUD AWS Sama-rinda (MBq)	DRL BAPETEN (MBq)	DRL Rajavithi Hospital Thailand (MBq)	DRL Korea (MBq)	DRL Kuwait (MBq)
Bone Scan	Tc-99m MDP	999	770	858,03	925	944
WBS	Tc-99m MIBI	921,3	1030	-	-	-
Thyroid WBS	I-131 Iodide	3739,227	150	-	185	200
Thyroid WBS	I-131 Iodide	3145	150	-	185	200

Based on Table 1 the DRL of the RSUD AWS Samarinda for the type of WBS examination using ^{99m}Tc MIBI is below the BAPETEN DRL value. This means that the WBS examination using ^{99m}Tc MIBI is in accordance with the recommendations of BAPETEN. Meanwhile, Thyroid WBS using ^{131}I and Bone Scan examination using ^{99m}Tc MDP are higher than the DRL value set by BAPETEN. In some conditions the administration of radiopharmaceuticals or high activity in patients is intended to obtain better images, especially in overweight patients. The size of the patient influences the amount of administered activity for producing appropriate image quality. Increasing the administered activity in nuclear medicine not only increases image quality but also saves acquisition time. Increase the image acquisition to reduce the administered activity while maintaining image quality. Long acquisition durations, on the other hand, are impractical because patients cannot remain motionless, and motion artifacts result in hazy pictures.

In case there are exceeded values, it should be investigated and, if necessary, a corrective action should be implemented. Because nuclear medicine DRLs are based on a specific activity, the optimization technique differs from other imaging modalities. If the institution routinely exceeds the required DRL values, this suggests that the physician and operator made poor decisions. If the images are low quality, it may suggest that the imaging equipment needs to be evaluated.

Based on Table 1 for Bone Scan examination, the DRL value of RSUD AWS Samarinda is higher than the BAPETEN DRL and also the DRL of Thailand, Korea, and Kuwait. In the WBS examination, the DRL of RSUD AWS Samarinda is below the BAPETEN DRL but no recent research was found on the DRL of the WBS examination using ^{99m}Tc MIBI. Meanwhile, in the examination of Thyroid WBS, the DRL of RSUD AWS Samarinda is higher than the DRL of BAPETEN as well as the DRL of Korea, and Kuwait. The DRL for the Thyroid WBS using ^{131}I at RSUD AWS Samarinda exceeds the BAPETEN DRL and this problem can be taken into consideration when evaluating the dose given to the patient at the next examination at the nuclear medicine installation.

4. Conclusion

Based on the results of the research that has been done, it is concluded that the DRL of RSUD AWS Samarinda on Bone Scan examination is greater than the DRL of BAPETEN and other countries i.e. Thailand, South Korea, and Kuwait. On WBS examination, the DRL of RSUD AWS Samarinda doesn't exceed the DRL of BAPETEN but no recent research related to WBS examination was found. While on Thyroid WBS examination, the DRL of RSUD AWS Samarinda is too high from the DRL of BAPETEN and other countries i.e Thailand, Korea, and Kuwait. The DRL values of RSUD AWS Samarinda for bone scan and thyroid WBS examinations are too high compared to the DRL values from other countries and BAPETEN. The high DRL value is expected to be a consideration to evaluate the dose given to patients in the next examination at the Nuclear Medicine Installation.

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