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Title: Establishing Local Diagnostic Reference Level for Bone Scintigraphy in a Nigerian Tertiary Hospital

Short Running Title: Local DRL for Bone Scintigraphy

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ABSTRACT

Background: It is of vital importance to optimize radiation dose to patients undergoing radionuclide bone scan. This is one of the most common nuclear medicine procedures in many parts of the world, including Nigeria. However, this study was carried out as part of a national survey to establish Diagnostic Reference Levels for common nuclear medicine procedures in Nigeria to facilitate optimization of medical exposure. It is important to state here that nuclear medicine was recently introduced in the healthcare system in Nigeria with only two centers presently conducting these procedures.

Methods: A retrospective, cross-sectional study was carried out in the Nuclear Medicine department of a tertiary hospital in Southwest Nigeria to determine the preliminary local Diagnostic Reference Level (DRL) for radionuclide bone scan. One hundred and nine (109) patients who met the study criteria were involved in the study. Data was obtained from June 2017 to March 2019 and analyzed to obtain the 3rd quartile value of the distributed administered activity and achievable dose, ***the mean ± standard deviation, the anthropometric variables, and radiation dose to bone surface***. Results: The result showed that the mean administered activity; achievable dose and DRL were 833.98± 106 MBq, 832.5 MBq and 895.4 MBq respectively. Furthermore, the calculated preliminary local DRL was found to be larger than values reported in studies done in Sudan, United Kingdom, Australia and ICRP.

Conclusion: We concluded that the preliminary DRL from the study being the first of its kind in Nigeria is high due to lack of experience from practitioners. However, values obtained are still within international best practice range which when optimized will go a long way to reduce medical exposure without comprising image quality.

Keywords: Administered Activity, Diagnostic Reference Level (DRL), Nuclear Medicine, Bone Scintigraphy, Image quality

Introduction

In the world of medical imaging, radiation protection especially as it relates to medical exposure of patients, is a major concern calling for intervention. This and many more necessitated the International Commission on Radiological Protection (ICRP) to recommend the principles of justification of practice, optimization of protection and dose limit to address fundamental radiation application and use. As for medical exposure however, dose limits are not applicable per se, as this would defeat the purpose of justification of practice (*1*).

There has been significant increase in the use of radiation for medical purposes and as such has led to concomitant medical exposure, dose to relatives and the environment **(***2***).** In the early 1990s, ICRP introduced the concept of Diagnostic Reference Level to address optimization of dose for medical exposure (*3,4*) in order to bring the minimum application of radiation to patients. According to Council Directive 97/43/Euratom, Diagnostic Reference Levels (DRLs) are dose levels in medical radiodiagnostic practices for typical examinations in groups of standard sized patients or standard phantoms for broadly defined types of equipment (*4*).

The establishments of Diagnostic Reference Levels (DRLs) and achievable dose (AD) ([1]) have proven to be effective tools that aid in optimization of protection in medical imaging (*5*)**.** DRL define the lower and upper limits of administered activities in Nuclear Medicine (NM) and in Radiology practice, and can be specifically applied to bone scintigraphy, which is the most common Nuclear Medicine procedure in Nigeria, as a sensitive diagnostic imaging method that

[1] *DRL and AD as defined respectively in the ICRP publication 135 as a form of investigation level used as a tool to aid optimisation of protection in the medical exposure of patients for diagnostic and interventional procedures and AD as the level of DRL quantity achievable by standard techniques and technologies in widespread use, without compromising adequate image quality i.e. value set at the median value(50th percentile) of the distribution of DRL quantity observed in a survey of department.*

uses a radiopharmaceutical to evaluate the distribution of bone formation relating to physiological processes in addition to malignant and benign disease. The examinations chosen for the DRL process should be those performed most often in the region for which dose assessment is practicable (*6*).

Therefore, the DRL is used to help avoid delivery of excess radiation in the form of a DRL quantity to the patient that does not contribute to the clinical purpose of a medical imaging task. This is accomplished by comparison between the numerical value of the DRL (derived from relevant regional, national, or local data) and the mean or other appropriate value observed in practice for a suitable reference group of patients (e.g. height, weight, age) or a suitable reference phantom (*6*). If it is found that procedures are consistently causing the relevant diagnostic reference level to be exceeded, there should be a local review of procedures and the equipment in order to determine whether the protection has been adequately optimized. If not, measures aimed at reduction of doses should be taken (*7*). DRLs in Nuclear Medicine are based on administered activities (AA) used for normal size patients (typically 70±15 kg) necessary for good image quality during a standard procedure (*8*).

The role of Nuclear Medicine in patient management of disease in a developing nation is as impactful as it is in other regions of the world. However, in the developing world, the practice of nuclear medicine is faced with a myriad of challenges, which can be easily avoided (*9*)**.**

Recently, there has been increased awareness globally on the need to strengthen radiation protection in medicine with the recent "Bonn Call for Action" established in 2012. Despite the fact that huge progress has been recorded by most developed countries in terms of radiation protection of patients, (*10*) the situation in most developing countries is still a far cry from ideal. Nigeria as

a country, based on existing records, does not have a local or national dose registry for Nuclear Medicine, which is important for establishing dose reference levels.

However, based on literature searched, no previous studies have been undertaken to establish diagnostic reference levels for radionuclide bone scan procedure in Nigeria. Therefore, optimization of protection is doubtful, as there are no records of references in our day-to-day nuclear medicine practice. Establishing DRLs is vital in Nigeria as it forms an all-inclusive tool for optimizing radiation protection of patients (*11*).

This study, therefore, addressed the challenge of optimization of radiation protection through the establishment of a preliminary DRL for bone scintigraphy as the most requested procedure, and the role achievable dose played in dose reduction albeit maintaining images of diagnostic quality.

Materials and Methods

Design

This is a retrospective and cross-sectional study carried out in the Nuclear Medicine Department of a tertiary hospital in southwest, Nigeria. The data in this study were collected from 2017 to 2019 that included one hundred and nine patients which were purposively selected. The center was chosen because it met the eligibility criteria for the study having the imaging modality of choice and facilities for the study.

Equipment Specification

Dose calibrator: The CRC-ISR Radioisotope Dose Calibrator was manufactured by Capintec, Ramsy NJ 67446, USA in March 2005. It has a voltage range of 100-240V, 50/60Hz and a current of 120mA.

Gamma Camera: The SPECT gamma camera Model 4369372 was manufactured by Siemens, USA in November 2005. It has a voltage of 200V, frequency 50/60Hz, 30mA and a line single phase.

Ethical Clearance

Ethical approval was obtained from the Research Ethics Committee of Oyo State Ministry of Health, Ibadan, Oyo state, Nigeria. Also;

- Data was anonymized.
- Data was kept confidential in a personal computer.
- Results did not contain any bio-profile of the patients and centre for the study

Procedure

Departmental documents and records were made available to the researcher who happens to be a former staff and one of the pioneer radiographers in the imaging unit of the centre. Data were generated and sorted accordingly to capture the needed details for the study. Departmental protocols that enhanced practice of bone scintigraphy were; prepared radiopharmaceuticals [Technetium-99m Methylene Di-Phosphate (^{99m}Tc-H/MDP)] measured with the Dose Calibrator in the radiopharmacy hot-lab and administered intravenously to patients referred for a radionuclide bone scan. Patients laid supine on the SPECT Gamma Camera for planar image acquisition. The departmental routine window and persistence remain unchanged for all procedure. The activity administered and other anthropometric parameters were recorded for each patient.

Method of Measurement

Dr. Jesus Luis Gomez Perales and Dr. Antonio Garcia Mendoza developed DOSISRAD® software made based on the values given by the International Commission on Radiological Protection

(ICRP) which was used to automatically calculate the absorbed dose to organs and effective dose from the administered activity of the radiopharmaceutical (*12*). This was performed in accordance with the requested investigation, clinical indications, patient's weight, the type of radiopharmaceutical and the administered activity (MBq).

Data Analysis

Data were obtained and saved on a computer Microsoft Excel Spreadsheet and categorized for the examination and anthropometric parameters. Statistical Package for the Social Sciences (SPSS, IBM, Chicago, USA) version 23.0 was used to analyze the mean and standard deviation of the administered activity, anthropometric variables, and radiation dose to critical organ (bone surface). The Achievable Dose (AD) and DRL value were obtained from the distribution of the administered activity for radionuclide bone scan. Parametric test was suitable as there was normal distribution at 95% confidence interval after using Kolmogorov–Smirnov method to test for normality of data distribution. Statistical significance was set at $P < 0.05$.

Results

The average activity administered was found to be 833.98MBq as seen demonstrated in figure 1 where comparison of the Average Administered Activity (AAA) from current study with Sudan AAA (*8*), BSS 1996 (*13*), UNSCEAR 2008 (*14*), Brazil (*15*), France (*16*) and Korea AAA (*17*) were clearly indicated. The current study shows lower AAA with respect to UNSCEAR standard and Brazil but higher than the rest of indicated organization and countries. Patients involved were between age 34-87 years (Table 1) signifying only adult patients were included in the study. Consideration pointed at the 50th percentile value (Table 2) which appears insignificantly lower

than the average administered activity. This value is recommended for use as a reference value to forestall excessiveness in the use of ionizing radiation.

Discussion

This study established preliminary DRLs for bone scintigraphy in a tertiary hospital, Southwest, Nigeria. There is only one teaching hospital in South Western Nigeria at the time of this study that offers the services of Nuclear Medicine in Nigeria. A total of one hundred and nine patients participated in this study.

Anthropometric Variables

The anthropometric variables as demonstrated in **Table 1** shows mean age, weight, height and Body Mass index (BMI) to be respectively 57.9±14 years, 71.6±6.7 kg, 1.63±0.5 m, 29.9±3.0 kg/m^2. The average BMI shows overweight patients were largely involved for various indications, while the maximum value falls within the severely obese class; 37.99kg/m^2 (35-40kg/m^2). This is so as obesity may have increased risk of many types of cancer such as cancers of the breast, colon, endometrium etc.

Administered Activity

The maximum activity administered was quite high; 1124.8 MBq (***Table 2***), less only to the value indicated by Brazil (1480MBq) from literature accessed by the researcher. This further demonstrated lack of standard protocols and unnecessary radiation dose, hence, the need for investigation of levels, dose audit, regulation and optimization of dose. The non-standardization of activities administered for the same type of imaging procedures can echo the deficiency of control of radiation exposure, and it was observed that there is wide range between the AA to the

patient for the same type of examination of over 44% between the minimum and maximum AA (*18*)**.**

Mean Administer Activity

Table 2 shows minimum, AD (50^{th} percentile/ 2^{nd} Quartile), mean and standard deviation of the Administered activity, critical organ dose and DRL for the radionuclide bone scan. The mean administered activity 833.98 ± 100 MBq translating to mean bone surface dose of 52.54±6.31mGy. The differences noted in the value of Average AA of the current study, though within international range, clearly outlines higher administered activity used unnecessarily, which in turn increased patient radiation dose. This indicates neither a guideline or reference value in place to guide in optimizing medical exposure that will earn the same result of diagnostic image quality.

Achievable Dose

Achievable dose represents the 50th percentile (*19*) (median) of the dose distribution from this study and as define by ICRP and IAEA. 832.5MBq was calculated as demonstrated in Table 2. However, as the second phase of optimization, Figure 2 shows that our calculated value is within the range of SNMMI, ASNR and EANM while it falls below those obtained by ACR and NCRP report. Achievable Dose has an additional role in filtering optimisation as some degree of patient dose reduction can be attained without affecting image quality undesirably. The extrapolation of this value into current practice for radionuclide bone scintigraphy could reduce the dose by approximately 26%. This value is highly significant in optimization of radiation dose to the patient.

Preliminary DRL

The Preliminary local DRL value (895 MBq) for Radionuclide bone scan in this study was found to be within EU range (Table 3), below the value indicated in Brazil (1110MBq) by a study conducted by Willegaignon et al (2016) and Austrailia (*20*). However, the value in the current study is higher than the DRL for bone scintigraphy in Sudan and United Kingdom (*21*). If it is found that procedures are consistently causing the relevant diagnostic reference level to be exceeded, there should be a local review of procedures and the equipment in order to determine whether the protection has been adequately optimized. If not, measures aimed at reduction of doses should be taken (*7*). Otherwise, practice during this developing phase in Nigeria has demonstrated a moderate level of safety, not excluding the fact that doses were sometimes administered not taking into consideration optimization of protection in achieving images of optimum quality. It therefore means if the DRL is put into use, it will help avoid unwarranted radiation dose to the patient that does not add to the value of clinical information obtained by the imaging protocols. Establishing a National Diagnostic Reference Level will serve as a tool for optimization of dose and as a guide for other Nuclear Medicine centres in the country.

Limitation

The study being a retrospective study shows some outliers that appear too small or large for age bracket and weight considered thereby leaving a room for caution in the applicability of the values.

Conclusion

Optimization of protection is doubtful as there are no records of references in our day-to-day practice in Nigeria. Based on relevant literature searched, no previous studies have been undertaken to establish diagnostic reference level for a radionuclide bone scan in Nigeria.

SPECT bone scintigraphy was identified as the most commonly referred investigation for Nuclear Medicine in southwest Nigeria. The study also determined the preliminary local DRL and AD for bone scintigraphy, which was found to be higher than in some countries and international bodies. Their application in subsequent studies will significantly reduce unnecessary medical exposure to patients undergoing this Nuclear Medicine procedures. In determining the minimum practicable radiation dose, there should be sound judgment and clear purpose in administering radiation to patients. Inconsistency in activity administered for the same procedure calls for concern, as wide differences in administered dose were noted without additional image quality, signifying a lack of local regulations, evidence-based protocols and standard operating procedure.

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Tables

Table 1: Descriptive statistics of anthropometric variables

	Age (Years)	***Weight (kg)***	***Height (m)***	***BMI (kg/m^2)***
Mean	57.9±14	71.6±6.7	1.63±0.5	29.9±3.0
Minimum	34	58.9	1.54	19.95
Maximum	87	85	1.77	37.99

Note- BMI= Body Mass Index

Table 2: Activity of dose administered to patients

Statistical Quantities	***Administered Activity (MBq)***	***Critical organ dose (mGy)***
Mean	833.98±106.93	52.54±6.31
Minimum	632.7	39.86
Maximum	1124.8	70.86
2nd Quartile (AD)	832.5	52.45
3rd Quartile (DRL)	895.4	56.41

Table 3: Comparison between local DRL (MBq) and international standard value(s)

Radiopharmaceutical	Current study	Sudan[8]	Australia[20]	United Kingdom[21]	EU[10]	Brazil[15]
^{99m}Tc-MDP Bone scan	895	777	920	600	500-1110	1110

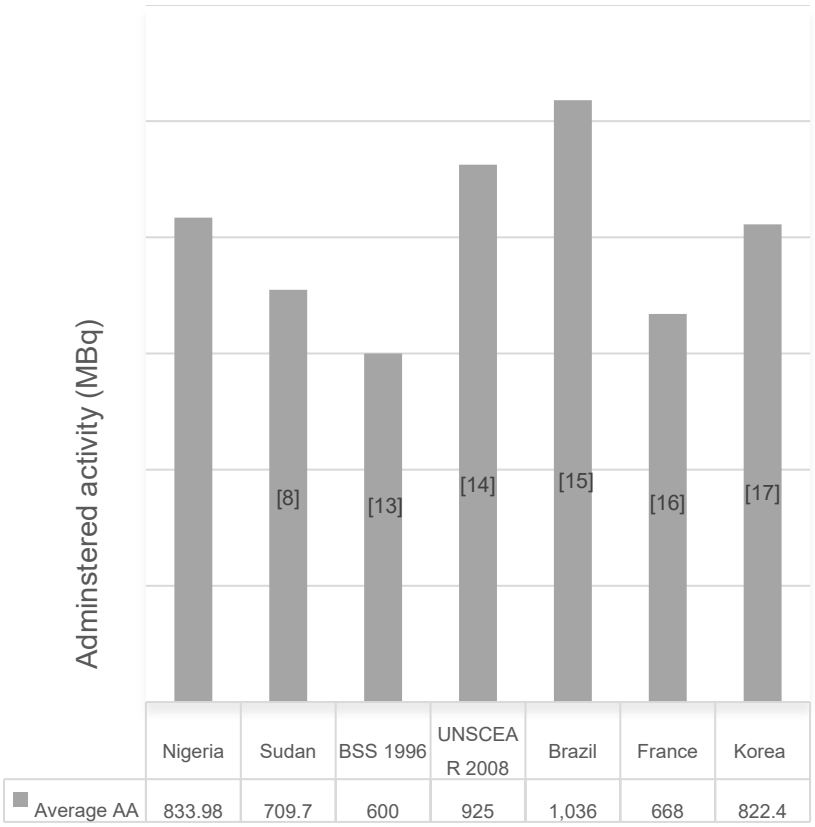

Figure 1: Comparison of Average administered activity (MBq)

N.B: BSS- Basic Safety Standard; UNSCEAR- United Nation Scientific Committee on the Effect of Atomic Radiation

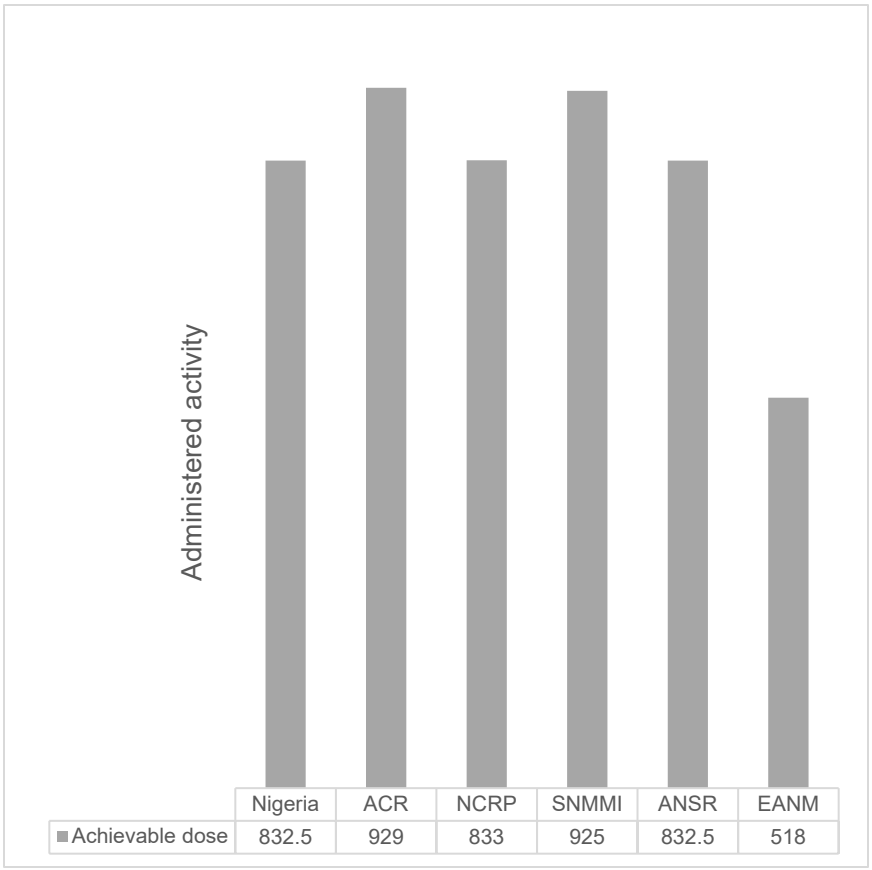

Figure 2: Comparison of AD[19] with other indicated in literatures

Note- ACR = American College of Radiology, NCRP= National Council on Radiological Protection, SNMMI= Society of Nuclear Medicine and Molecular Imaging, ASNR= American Society of Neuroradilogy, EANM= European Association of Nuclear Medicine

Graphical Abstract