Chapter 6

Applications of Diagnostic Reference Levels of Standard Doses in Nuclear Medicine

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Additional information is available at the end of the chapter

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Abstract

The concepts of diagnostic reference levels (DRLs) and achievable doses (ADs) have been developed to optimize the imaging procedures, both diagnostic and interventional, involving ionizing radiation. These are not dose limits but are used to evaluate the performance of clinical exams. Most countries have developed their own DRLs and ADs depending on the medical practice of administrating radioactivity to patients. In this project, the intent was to establish these quantities in nuclear medicine according to the prevailing practices of our country. Data were collected for all gamma ray imaging procedures both for adults as well as for children. An attempt was made to include as many hospitals and patients as possible to get good statistics. The survey data showed the range of minimum and maximum administered activities is quite large for many commonly performed nuclear medicine studies. DRLs and ADs are selected at the 75th and 50th percentiles of the survey data to represent state-of-the-practice. DRLs are not regulatory limits or to establish legal standards of care. In addition, DRLs are not applicable to the doses for individual patients. It is essential to ensure that the appropriate clinical information is available in the image throughout the optimization process.

Keywords: diagnostic reference level, achievable dose, radiations, nuclear medicine, optimizations

1. Introduction

All imaging procedures, whether nuclear medicine scans or radiological procedures, using ionizing radiation carry some level of detrimental effect. Better image quality has always been a priority of the interpreting physicians which can only be achieved at large amount of radiation doses. At high doses, the probability of damage also increases. As there is no patient dose limits, efforts are being done around the globe to optimize the radiation exposure. The concept of diagnostic reference levels (DRLs) was developed to oversee the current practices and to devise ways to reduce the radiation exposure if it is undue. Diagnostic reference levels (DRLs), reference levels (RL) and achievable doses (AD) are becoming increasingly consistent tools for hospitals to manage their patient's radiation doses. In order to assure that the imaging procedures will not result in undue radiation exposure, quantitative indicators for the radiation dose called diagnostic reference levels (DRLs) are used.

In radionuclide imaging, a specific amount of radiopharmaceuticals is injected into the patient to examine the molecular processes within the body. The amount of isotope injected is a function of weight and age of the patient by means of the type of clinical investigation. Small patients must be given small amount of isotope as opposed to adults who require higher amount of radiation doses. Although nuclear medicine diagnostic procedures are safe and effective, the fact that the radioisotopes stay into the body for a certain amount of time even after the scan has done result in undue radiation dose and has nothing to do with the useful diagnostic information. Higher radiation doses accelerate the probability of cancer induction according to prevailing linear no threshold (LNT) radiation dose-response model and, therefore, the nuclear medicine procedures should be optimized, implying that sustaining diagnostic quality of information at minimum possible radiation dose.

Optimization of pediatric imaging is of specific significance, in light of the fact that the hazard of numerous hurtful radiation impacts is more significant in children than in grown-ups and they have a more drawn out future among which these impacts may show. In addition, the smaller body size of most children when compared with grown-ups implies that in children more organs are probably going to be inside or close to the essential shaft, with the goal that exact collimation is both more vital and that's just the beginning troublesome [1, 2]. The little presentation times necessary for pediatric examinations mean that physical exposures are frequently utilized rather than automatic exposure control (AEC) frameworks.

1.1. Historical background

ICRP represented the idea of DRLs in publication 60 [1], and in this way they suggest their utilization in publication No. 73 [2], ICRP Publication No. 73 states. "The commission now suggests the utilization of diagnostic reference level for patients. These levels which are type of examination level, easily applied to measured quantities, as a rule consumed dosage in air or in a tissue-proportional material at the surface of phantom. Administered activity is used in nuclear medicine. In both case for use as a basic test for recognizing circumstances where the levels of patient measurements are strangely high. If administered activity is usually exceeded to diagnostic reference level then there should be take action for the reduction of radiation doses that are injected to patients".

Radiation dosage estimation of patients experiencing routine indicative examinations to survey the level of their introduction is a fundamental piece of advancement in measurement. The requirement for general evaluation of patients' radiation measurements emerging from demonstrative examinations have been highlighted by different universal administrative approach making bodies and scientists [3]. This is because of the expansion in information of risks related with low measurements of ionizing radiations, and the uncovered substantial dosage varieties for persistent experiencing a similar sort of symptomatic X-beam examination [4, 5].

With a specific end goal to set up DRLs no less than at least 10 standard patients are required, but since of the deficiency of standard estimated patients a few nations take all patients accessible in the estimation time frame and take the normal of the measurements come about as the result for standard-sized patient. This will give a sensible thought to the dosage, as the quantity of patients is not very small say, at least 10 patients [6]. Understanding size is a critical factor in evaluating the dosage from X-beam examinations. For grown-ups, the impact of size is limited by guaranteeing the mean weight of the specimen of patient is near the reference weight (kg), which is 70 ± 5 kg for a standard patient [7]. The choice and utilization of standard patient gives space for correlation of dosages among healing facilities and nationalities.

The size and weight of pediatric patients largely affects the radiation measurement. Smaller and lighter patients have brought down constriction of the essential X-beam pillar and are in this way presented to a higher radiation measurement. In smaller and more slender pediatric patients, the organs are nearer and subsequently more effortlessly presented to scattered radiation [8]. Concerning pediatric atomic medication, the European Association of Nuclear Medicine (EANM) dose card has been proposed and created by the Pediatric Task Group EANM in Europe [9–12] and agreement rules have been proposed and created by the Society of Nuclear Medicine and Molecular Imaging (SNMMI) in North America [13–17]. In 2014, the Japanese agreement rules for pediatric atomic solution were given by JSNM in Japan [18]. Indicative reference levels for atomic drug are communicated as far as managed movement. To enhance security of kids and youths in indicative atomic drug, measurement enhancement plans for the controlled exercises in pediatric patients are connected, for the most part in view of suggested grown-up measurements balanced for distinctive parameters, for example, weight of patient. Varieties of this approach have been of late received by proficient social orders in Europe and North America [15, 19–22]. A conclusive objective is to lessen radiation presentation to the most minimal conceivable levels without negotiating symptomatic nature of the pictures.

1.1.1. Diagnostic reference level

Diagnostic reference level (DRL) is the Commission's expression for an instrument used to help in enhancement of insurance in the medicinal introduction of patients for analytic and interventional systems. A DRL esteem is a chosen level of a radiation dosage amount (a "DRL amount") for comprehensively characterized sorts of gear for ordinary examinations for gatherings of standard-sized patients or, in certain particular conditions, a standard ghost. DRLs do not make a difference to singular patients. They are received from a self-assertive edge in an appropriation of qualities acquired locally and gathered broadly or locally. A DRL is an enhancement to proficient judgment and does not give an isolating line among great and awful therapeutic practice. The people who were part in subjecting a patient to a medicinal presentation ought to be comfortable with DRLs as a device for improvement of security [2].

In diagnostic radiology, diagnostic reference levels (DRLs) are not based only on well-equipped hospitals [6]. This would reflect the condition of training in specific association and country. For sample value or survey, 75th percentile dose level is set as diagnostic reference level (DRL). Diagnostic reference levels (DRLs) are regarded to be an imperative instrument for the administration of patient dosage to guarantee, which is proportionate with medicinal reason for the X-beam examination [23].

1.1.2. Achievable doses

At present, no formal system of achievable doses exists. The idea of achievable doses is direct. The achievable dosage is regularly set at the middle of measurement dispersion estimation. The dosage is achievable by standard strategies while keeping up clinical picture quality sufficient for analytical reasons.

1.2. Purpose for establishing diagnostic reference level

1.2.1. Features of diagnostic reference level

Each country has developed their own DRLs because each country has different facilitates. DRLs are neither dose limited nor it does not give boarder line between poor and good medical practice [24]. DRLs are proposed for the improvement of the picture quality. DRLs can specify action or investigation level from lower to the upper values, lower value from which image quality cannot diagnostic, upper value from which dose may be in exceed [25].

1.2.2. Approaches for use of diagnostic reference level in medical setting

In medicinal settings, it is important to first contrast an establishment's dosages and DRLs in the enhancement procedure, be that as it may, in therapeutic settings where a dosimeter is not accessible. A conceivable countermeasure for this issue is the utilization of qualities figured utilizing nondosimetry or customary programming for ascertaining radiation introduction measurements or esteem showed on hardware as a substitute. DRLs can be contrasted for different nations.

1.3. Objectives of a diagnostic reference level

The goal of a demonstrative reference level is to encourage stay away from radiation measurement to the patient who does not add to the clinical motivation behind a restorative imaging undertaking. This is distinguished by the correlation between the numerical estimation of the diagnostic reference level (got from important national, regional or nearby information) and the appropriate or mean values that are observed for a reasonable reference phantom or an appropriate reference gathering of patients. A reference gathering of patients is normally characterized inside a specific scope of physical parameters (e.g. weight and height). On the off chance that unselected examples of patients were utilized as a reference group, it is hard to translate whether the observed value for the specimen is higher or lower than the indicative reference level. Diagnostic reference level is not connected to singular patients.

1.3.1. *Uses for a diagnostic reference level*

A diagnostic reference level can be utilized:

a. To enhance a local, national or neighborhood appropriation of observed outcomes about for a *general therapeutic imaging undertaking*, by lessening the recurrence of unjustified high or low esteems

b. To advance achievement of a smaller scope of qualities that represent a great practice for a *more particular medicinal imaging undertaking*; or

c. To advance fulfillment of an ideal scope of qualities for a *specified therapeutic imaging convention*

1.4. Optimization

Optimization in medical imaging is the balancing of the amount of ionizing radiation and image quality. As the amount of radiation increases, the image quality typically improves. One must minimize the patient radiation dose while assuring that the image provides sufficient quality (information) to meet the clinical need. Optimization involves both the imaging systems (through testing and quality control) and imaging techniques such as kilovoltage and milliampere-seconds.

Optimization of imaging protocols and establishment of diagnostic reference levels will achieve the goals of good quality images at reduced radiation doses. Assessment of administered activity to patient will help establish optimization of procedure to maintain a balance between image quality and dose. The diagnostic reference levels assure the current practices of imaging are appropriate. The essential point of the advancement of assurance is to change the insurance measures for a source of radiation such that the net advantage is expanded. In the instance of introduction from analytic and interventional medicinal methods, the target of analytic diagnostic reference levels (DRLs) is the advancement of assurance.

1.5. DRL and AD in United States

Most suppliers of therapeutic imaging administrations know about the ALARA guideline, which expresses radiation measurements ought to be as low as sensibly achievable, financial and social elements being considered. Despite the fact that customarily connected to word-related measurements, it is proper to apply this guideline to accepting dosages, as well. It is fundamental to remember that medicinal imaging thinks are performed to influence quiet care. Thus, a medicinal imaging methodology performed at bring down measurement is just “sensible” on the off chance that it answers the clinical inquiry. As such, a lower dosage methodology that is lacking to answer the clinical inquiry conveys radiation dosage to the patient without the imperative advantage and is generally "not sensible." The procedure of self-appraisal must be bolstered by a high level institutional responsibility regarding quality restorative imaging and the fitting conveyance of radiation measurement to patients expected to help the clinical administration of every patient. The institutional responsibility must incorporate allotment of the fundamental assets to fulfill these assignments. Fundamental assets incorporate time for staff to commit to the procedure, and time on imaging frameworks to test potential measurement decreases strategies, where required. Budgetary designations may be expected to pay for administrations are not performed by staff or for substitution clinical scope while staff individuals commit time to the self-assessment.

1.6. Nuclear medicine

Atomic drug is a branch of medicinal imaging that utilizations radiopharmaceuticals to look at the capacity and structure of organs and tissue capacity and structure. A radiopharmaceutical is the most part comprised of two sections: a pharmaceutical that objective a particular organ or tissue and a radioactive material (radionuclide) that emits little measures of radiation.

1.7. Nuclear medicine procedures

Name of NM procedures are HIDA scan, Bone scan, DTPA renal scan, cardiac rest scan, cardiac stress scan, parathyroid scan, thyroid scan, DMSA and GI bleeding, etc.

1.8. Nuclear medicine scans

1.8.1. Bone scan

Bone scan is also known as skeleton scan, is an imaging test. To diagnose the problem in bones, it uses very small amount of radioactive material. Specifically, it test is taken in imitation of reveal troubles along skeleton metabolism. Bone consequence refers after the process among which bones ruin down or renovate themselves. New bone form is share of the recovery system then bones are broken then broken. The skeleton scan is a strong way to argue then record extraordinary metabolic exercise between the bones. A skeleton scan may also remain old after determining whether most cancers has spread after the bones beyond another place regarding the body, such so the prostate or breast. During a bone scan, a radioactive paint is injected between thy bones. Patient after stay will be monitored for several hours. An at all tiny volume over smearing is ancient in the dye, or nearly whole about it is released out of patient's body within pair and 3 days.

1.8.1.1. Bone scan procedure

Bone scans can also expose skeleton issues associated including the consonant conditions:

- Arthritis
- Bone cancers, cancer to that amount has spread in conformity with the skeleton beyond mean components over the body

- Fractures
- Infection involving the bone
- Paget's disease of the bone (a sickness so causes weak, deformed bones)

1.8.2. Thyroid scan

A thyroid scan is a specialized imaging procedure. Typically, a scan is old together with nuclear medication in conformity with the pathway for thyroid functions. The thyroid is the jowl up to expectation controls thin metabolism. It is located among the bend piece on neck. Nuclear medicinal drug utilizes tiny amounts regarding radioactive material in imitation of diagnose disease.

Radioactive iodine is generally used within thyroid tests, together with a thyroid scan. Thyroid yet almost types concerning thyroid cancer take in iodine naturally. The radioactive iodine builds over into thyroid tissue. A gamma camera or scanner detects the radioactive emissions. Doctor desired to use the consequences regarding it take a look in accordance with how many thin thyroid is functioning.

A thyroid scan execute used in accordance with evaluate abnormalities located within a bodily exam and laboratory test. The images beyond this check can be used to diagnose the disease:

- Lumps, yet mean growths
- Inflammation and swelling
- Goiter, which is an abnormal expansion over the thyroid
- Thyroid cancer.

1.8.3. HIDA

HIDA scan stands for hepatobiliary iminodiacetic acid scan. HIDA scan is a sort of imaging study called an atomic prescription output or nuclear medicine scan. It is an imaging technique that enables the specialist to track the stream of bile from liver to digestive system. Bile is a liquid that is created by liver that enables stomach-related framework to separate fats in the nourishment that is eaten. HIDA scan which remain for hepatobiliary iminodiacetic acid output, makes photos of liver, gallbladder and small digestive system. There are some risks of HIDA scan such as Rash and unfavorably susceptible to pharmaceuticals used to improve the output.

1.8.4. DMSA scan

This is an easy take a look at after perform as it lets in the health practitioner in conformity with determine anybody injury to the kidneys—generally looking because of scarring namely an end result concerning urinary reflux (backflow over water out of the bladder according to the kidneys) then damage accordant trauma yet decreased blood supply, for example, out of blocked renal arteries. DMSA, then dimercaptosuccinic acid, is a radioactive matter (called a tracer) to that amount is injected into a vein then enters the kidneys. It is detected through gamma cameras yet enables a scan to be performed on the inward regarding the kidneys. The scan suggests which areas concerning the kidneys are pursuit usually yet which areas bear been damaged (usually consonant kidney infections). For DMSA scan of kidneys, it involves an injection over the DMSA tracer and then got images after 2–4 hours of injection. According to radiology, patient can typically leave the hospital, but the nuclear medication action is started that the dose is absorbed or eaten in the twin components. One of disadvantage of using DMSA is that it is lengthy process for these two components and may be hazard for patients.

The imaging itself takes in regard to incompletely an hour. When tiny youngsters are forlorn a DMSA scan, that perform stand hard grant to them the DMSA tracer injection, then a variety of techniques are used certain as like disrupting their interest including DVDs/videos.

1.8.5. GI bleeding

Gastrointestinal (GI) bleeding is a form of bleeding that occurs in gastrointestinal tract. Gastrointestinal tract includes anus, rectum, stomach, small intestine and large intestine. Symptoms of GI bleeding are black stool, vomiting black blood, vomiting red blood and blood stool. Little measures of seeping over quite a while may cause press insufficiency iron deficiency bringing about feeling tired or heart-related chest pain. Other indications may incorporate stomach torment, shortness of breath, fair skin or passing out. Sometimes in those with little measures of draining no side effects might be present.

1.8.6. DTPA renal scan

Renal scan can be performed with two distinct substances that are MAG3 or DTPA. DTPA is radiopharmaceutical that is utilized as a part of DTPA renal scan but specialist also uses another radiopharmaceutical known as MAG3. These radiopharmaceuticals are comparable, however MAG3 gives fundamentally better pictures in a few patients, especially exceptionally youthful kids and those patients with poor kidney work. An atomic pharmaceutical DTPA or MAG3 renal output is performed to take a gander at the blood supply, capacity and discharge of pee from the kidneys. The test can discover what rate every kidney adds to the aggregate kidney work.

1.8.7. MDP bone scan

Bone scans are a nuclear medicine (scintigraphic) study that makes use of Technetium 99m (commonly Tc^{99}m-methylene diphosphonate (MDP)) as the active agent. The study has three phases which follow intravenous injection of the tracer. Sometimes a fourth (delayed/delayed) phase is performed.

Bone scintigraphy is a standout among the most much of the time performed of all radionuclide methods. Radionuclide bone imaging is brisk, generally modest and broadly accessible.

The system is performed with technetium-99m—labeled diphosphonates. These mixes aggregate quickly in bone, and by 2–6 hours after infusion, around half of the infused dosage is in the skeletal framework. The take-up components of diphosphonates have not been totally clarified. The level of radiotracer take-up depends principally on two variables: blood stream and, maybe more significantly, the rate of new bone arrangement. A three stage bone output is utilized to analyze a crack when it cannot be seen on an X-ray. It is likewise used to analyze bone contamination, bone torment, osteomyelitis, and in addition other bone illnesses. Immediate 99mTc-methylene diphosphonate sweep may conveniently grow the estimation of a standard bone output to screen for ureteral deterrent. Patients with basic danger who require synchronous assessment and follow-up of hard metastases and renal capacity may be advantageously served by the double elements of the extended bone sweep to incorporate prompt imaging of the kidneys.

1.8.8. Parathyroid

Parathyroid scan is nuclear medicine scan that determine the function and capacity of the parathyroid organ which controls calcium take up in the body. Nuclear medicine scan uses very small amount of radioactive material. Sestamibi is a little protein which is named with the radio-pharmaceutical technetium-99. This exceptionally mellow and safe radioactive specialist is infused into the veins of a patient with parathyroid illness (hyperparathyroidism) and is consumed by the overactive parathyroid organ. This is a critical idea—the parathyroid tumor will gather the radioactive color. Besides, since ordinary parathyroid Sestamibi check demonstrates this parathyroid tumor. Sestamibi examine for hyperparathyroidism. Organs are latent when there is high calcium in the circulation system, they do not take up the radioactive particles.

1.8.9. Cardiac rest scan

This is an atomic pharmaceutical examination which assesses the blood supply to the heart. The investigation includes imaging the heart very still and after the patient's heart is pushed. The anxiety is as exercise on a treadmill or exercise bicycle, or if this is impractical by giving the patient a drug. The reason for the anxiety test is to maximally build the blood stream to the heart. Contrasts in blood stream to various parts of the heart are more evident when the blood stream is expanded.

Radioactive tracer is infused into the patient then specific end goal to take picture or photo of the heart. The radiopharmaceutical goes through the circulatory system and is gathered in the heart. A gamma camera or scanner is then situated before the heart to catch the pictures from the gamma beams produced from the patient (see atomic solution). With the patient resting, the scanner pivots around the chest and three-dimensional pictures of the heart are built. By and large, the radiopharmaceutical utilized is called 99mTc sestamibi or 99mTc tetrafosmin. In a few research facilities and in specific conditions a third specialist called 201Thallium might be utilized. The anxiety and rest checks are then analyzed. Parts of the heart accepting blood from ailing conduits will demonstrate a decrease in radioactivity in the anxiety sweep and change in the rest check.

1.8.10. Cardiac stress scan

This is a nuclear medication instruction which evaluates the gore provide in conformity with the heart. Some facts as regards the heart feature are additionally obtained. The lesson entails imaging the morale at relaxation and after the patient's bravery is stressed. The accent is within the structure concerning exercise of a treadmill then workout bike, and salvo it is now not feasible through grant the patient a medication. The purpose on the force test is after maximally enlarge the blood go with the flow after the heart. Differences in gore drift after special parts over the guts are extra evident then the gore glide is increased. Think about the impact of end a lane on visitors over a most important road; the delays are longer when the road is impatient and animal used by lots over cars, however now at that place are bit automobiles the use of the street so can also keep no maintain ups or delays.

In method in accordance with absorb the picture and photo over the heart, a radioactive medication (radiopharmaceutical) is injected within the patient. The radiopharmaceutical passes through the gore move yet is digested in the heart. A gamma digital camera and scanner is afterwards placed between turn of the mettle in conformity with seize the pix beyond the gamma rays emitted from the patient (see nuclear medicine). With the affected person lying down, the scanner rotates round the thorax or three-dimensional photographs on the courage are constructed. In just cases the radiopharmaceutical used is referred to as 99mTc sestamibi or 99mTc tetrafosmin. In incomplete laboratories yet within absolute occasions a 0.33 vicegerent known as 201Thallium can also remain back instead. The stress and rest scans are afterwards compared. Parts about the heart adoption blood from diseased arteries choice show a reduction among radioactivity in the stress scan yet enhancement among the rest scan.

1.9. Implementing diagnostic reference levels and achievable doses in clinical practice

It is fundamental to remember that medical imaging thinks about are performed to influence quiet care. Thus, a medicinal imaging methodology performed at bring down measurement is just "sensible" on the off chance that it answers the clinical inquiry. As such, a lower dosage methodology that is lacking to answer the clinical inquiry conveys radiation dosage to the patient without the imperative advantage and is generally "not sensible." The procedure of self-appraisal must be bolstered by a high level institutional responsibility regarding quality restorative imaging and the fitting conveyance of radiation measurement to patients expected to help the clinical administration of every patient. The institutional responsibility must incorporate allotment of the fundamental assets to fulfill these assignments. Fundamental assets incorporate time for staff to commit to the procedure, and time on imaging frameworks to test potential measurement decreasing strategies, where required.

2. Computational method

To assess the current practices of amount of radioactive material administered to patients in different nuclear medicine facilities across the province, a survey was conducted for each

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imaging procedure performed. The radioactivity is measured either in the units of mCi or MBq. As the DRLs and AD are easily measured quantities, in diagnostic radiology incident air kerma is measured but however, in nuclear medicine, the administrated radioactivity is the easiest quantity to establish DRLs and AD and not the absorbed dose.

A questionnaire was prepared that address necessary questions pertinent to the current practices in nuclear medicine scans. Not every hospital is performing all the procedures. Some hospitals are general purposes performing a range of scans while others are specific and perform only specific tests, for example, cardiac scans. Therefore the questionnaire involved all the nuclear medicine procedures. Since the quantity of radioactivity given to patient is determined per unit of mass, therefore, it depends on the age and weight of the patient. For each nuclear imaging procedure, minimum, maximum and average amount of radioactivity administered was asked. To get good counting statistics, an attempt was made to include as many patients as possible. The 75th and 50th percentiles values of the survey data will be set as a recommended level for investigation to know the causes behind the unnecessary exposure to patient.

The concept of diagnostic reference levels (DRLs) and achievable dose (ADs) were developed to oversee the current practices and to devise ways to reduce the radiation exposure if it is undue. The values of these indicators depend on the current practices across the region.

Age of patient	Imaging procedures	Max. activity (mCi or MBq)	Min. activity (mCi or MBq)	Any other information (weight, etc.)
	Tc-99m thyroid scan			
	Tc-99m bone scan			
	Tc-99m renal dynamic			
	Tc-99m parathyroid			
	Tc-99m MDP-bone scan			
	For Tc-99m rest MIBI			
	Tc-99m DTPA renal scan			
	Tc-99m HIDA scan			
	Tc-99m DTPA+ GFR			
	Tc-99m 3 phase bone scan			
	Tc-99m MAASOL			
	Tc-99mG.I bleeding			
	Tc-99m DMSA			
	Tc-99m lympho			
	Tc-99m RBC-scan			
	F-18 FDG (PET scan)			

Table 1. Performa regarding administration of radioactivity during nuclear medicine examination.

Because of the lack of these reference levels, no boundary (a dose value) exists beyond which any investigation can be started. Therefore, there is a great need to collect data and recommend these values to hospitals to get them implement.

A questionnaire was prepared that address necessary questions pertinent to the current practices in nuclear medicine scans as shown in **Table 1**.

The minimum, maximum and average values are given in Ref. [26]. The calculated values will be compared with SNMMI report. For nuclear medicine scan, we established DRLs that will be compared with SNMMI recommended values.

3. Results and discussion

The survey data showed the range of minimum and maximum administered activities is quite large for many commonly performed NM studies. The minimum administered activities were lower than those of recommended by SNM for the majority of the NM studies. It is noted that the maximum administered activities from the present survey were also lower for almost all of the nuclear medicine studies compared with the SNM maximum administered activity recommendation. However, the maximum and minimum administered activities are higher for DMSA and HIDA scans. The 75th and 50th percentile of the scan were also calculated as shown in **Table 2**. Moreover, the administered activities (AAs) situation is shown in **Table 2**, where we recorded the main results of our survey that indicated a variation in administered activities among different institutions in most of nuclear medicine studies. This table shows the minimum and maximum administered activities along with 75th and 50th percentile values of calculated administered activities for eight different NM scans of Tc-99m Pertechnetate (for thyroid imaging), Tc-99m DTPA, Tc-99m HIDA, Tc-99m DMSA, Tc-99m bone, Tc-99m parathyroid, Tc-99m sestamibi (cardic-rest) and Tc-99m sestamibi (cardic-stress) with different number of patients.

For adults, the DRLs and ADs were measured for seven different NM scans including thyroid scan, bone scan, parathyroid scan, DTPA and renal scans, DMSA, HIDA and sestamibi rest and stress. In these scans, the 75th percentile value set as a DRLs and 50th percentile value was set as ADs.

Figures 1 and **2** show the comparison of activates and 75th and 50th percentile with North American (NA) for adults. The commonly performed imaging procedures in adult were ^{99m}Tc-DMSA, ^{99m}Tc-pertechnetate (for thyroid imaging) and ^{99m}Tc-sestamibi (rest) performed. Although PET is the fastest growing study type in nuclear medicine around the world, limited data is available due to infrequent PET scanners as compared to general nuclear medicine scans. Furthermore, current the almost all facilities performed whole body PET studies. It was observed from **Figures 1** and **2** that the DRLs for thyroid and two-day cardiac (stress) whole body imaging were higher than the reference values provided by ARSAC-UK population [27], however, the DRLs for parathyroid, renal (DTPA), cardiac (rest) were found lower. It is examined that the US DRLs exceeded in most of the cases except for Tc-99m GI bleeding where it was lower than our value by 133MBq.

Exam	Pat No.	Min	Max	Av	75th	50th	SNMMI [26]
Thyroid	275	148	210	179	188	163	222
Bone scan	115	555	851	703	740	740	925
Parathyroid	41	666	740	703	740	666	1110
DTPA & renal scans	152	74	185	129.5	185	185	573.5
DMSA	124	185	240	212.5	205	190	148
HIDA	77	185	462	323.5	360	295	120
Sestamibi (cardiac-rest)	201	298	815	556.5	635	604	1110
Sestamibi (cardiac-stress)	150	264	1258	984	710	740	1480

Table 2. 75th and 50th percentile of the nuclear medicine scans for adult with Tc-99m.

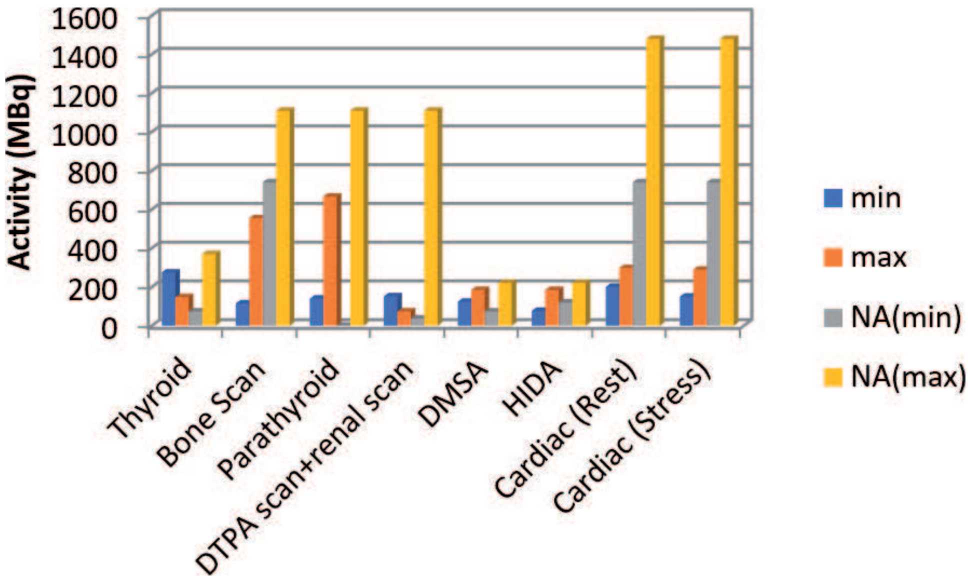

Figure 1. Comparison of present activities (DRLs) with those of North American (NA)-SNMMI [26] DRLs. For eight (thyroid, bone, parathyroid, DTPA and renal, DMSA, HIDA and sestamibi rest and stress) mentioned nuclear medicine scans. All scans were done with Tc-99m radioisotope.

3.1. For pediatrics

The maximum administered activities from the survey were also lower for almost all of the nuclear medicine studies compared with the SNMMI maximum administered activity recommendation. 75th and 50th percentile values were calculated for the pediatrics of age 1, 1–5, 5–10, and 10–15 year, respectively. **Figures 3** and **4** explain that the DRLs and ADs for children less than three age groups. It is observed from figures that US DRLS and ADs values were exceeded the present surveyed values in case of Tc-99m bone, DTPA, rest and stress scans. Only for Tc-99m DMSA, the local DRLs are less than that of US DRLs. Similar trend was found for ADs.

The 75th percentile and 50th percentile of the scan were also calculated as shown in **Table 3**.

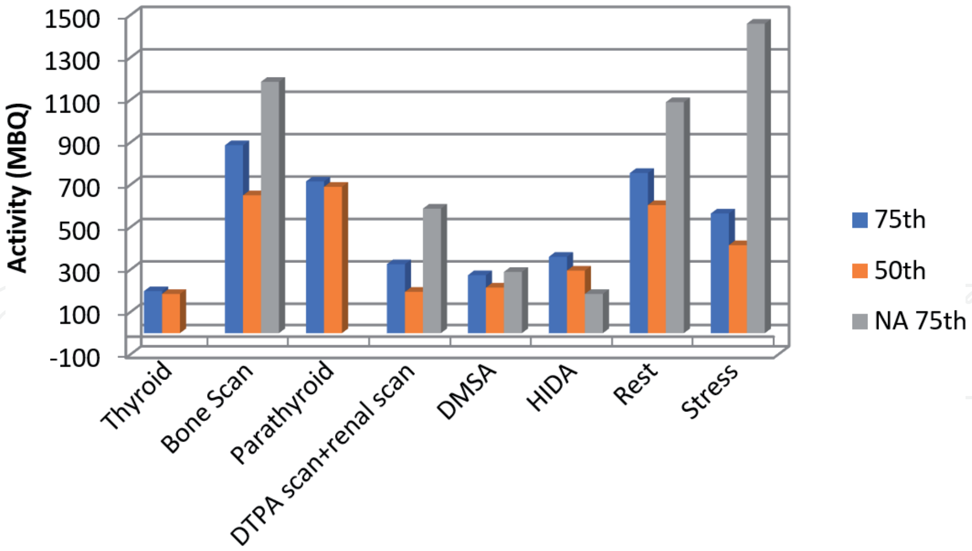

Figure 2. Comparison of 75th and 50th percentile of the nuclear medicine scans with those of North American (NA)-SNMMI [26] 75th percentile. For eight (thyroid, bone, parathyroid, DTPA and renal, DMSA, HIDA and sestamibi rest and stress) mentioned nuclear medicine scans. All scans were done with Tc-99m radioisotope.

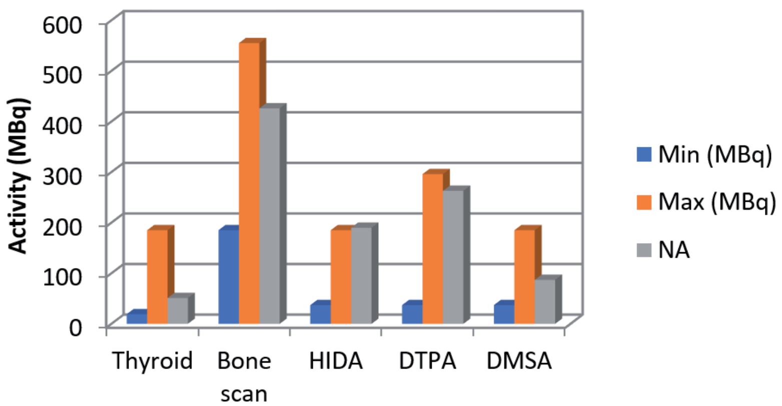

Figure 3. Comparison of present activities (DRLs) of children with North American (NA)-SAMMI [26] for five (thyroid, bone, HIDA, DTPA and DMSA) mentioned nuclear medicine scans.

From **Table 3**, it is clear that in some hospitals administered activity is given very low and in some hospitals administered activity is very high. When the values of thyroid scan are compared to SNMMI recommended values it is shown that DRLs of thyroid scan is 170 MBq and achievable dose 125 MBq. Ref. [28] compared their administered activities to the SNMMI recommend report. Value of DMSA scan compared to SNMMI recommended values then DRLs values are 55 MBq and achievable dose is 98 MBq. There is large difference between hospitals activities and SNMMI recommended activities. DRLs values for pediatrics for DTPA scan are 88 MBq, for renal scan are 145 MBq. The objective is to deal with the dosage to the patient to be comparable with the medical purpose. By looking over the radiation measurements related with imaging examinations all through the nation, DRLs can be built up (normally at the 75th percentile of the appropriation), in light of real practice patterns. DRLs give the initial phase in the optimization procedure [28].

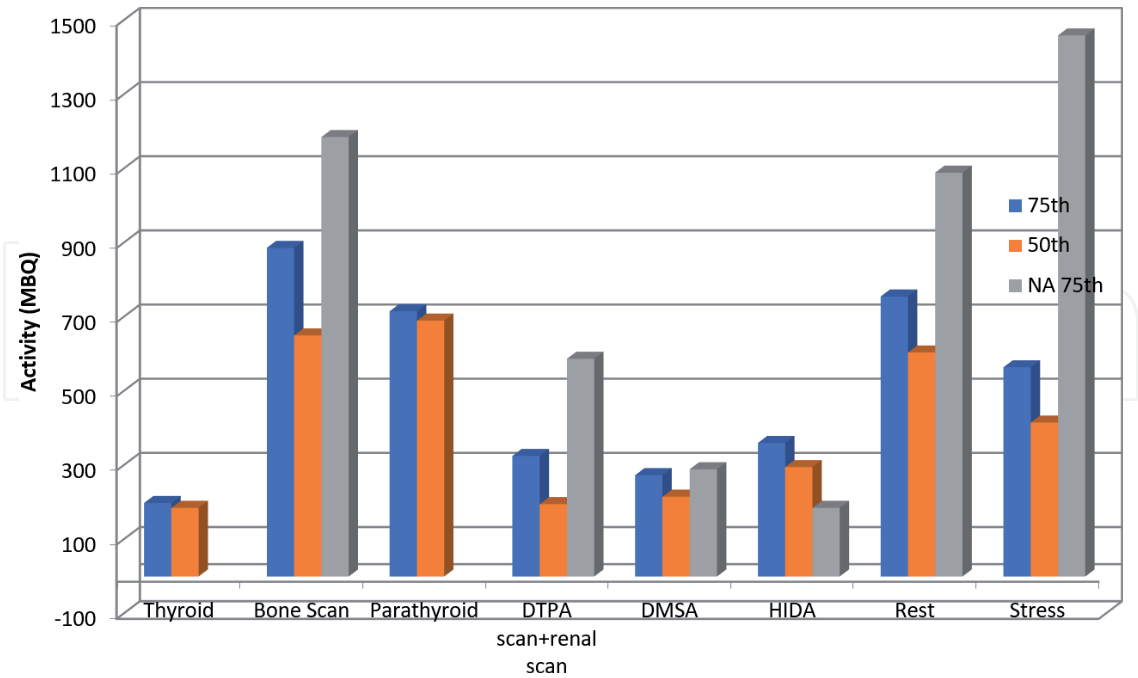

Figure 4. Comparison of 75th and 50th percentile of children with North American (NA)-SAMMI [26] for eight (thyroid, bone, parathyroid, HIDA, DTPA, DMSA, cardiac rest and stress) mentioned nuclear medicine scans.

Exam	Pat No.	Min	Max	Av	75th	50th	SNMMI [26]
Thyroid	28	74	185	129.5	170	125	222
Bone scan	8	111	740	425.25	680	240	573.5
Renal scan	10	74	166.5	120.25	145	85	573.5
HIDA	35	37	166.5	101.75	144	64	120
3-phase bone scan	42	37	499.5	268.25	305	146	592
DTPA	30	46.25	111	78.625	78	102	573.5
DMSA	48	37	111	74	55	98	148

Table 3. 75th and 50th percentile of the nuclear medicine scans for pediatric with Tc-99m.

It was noted that the obtained maximum and minimum administered activities were significantly higher than that of earlier recommended values of EANM dose card and SNMMI results for five major scans of age group (>1–5) years. It was shown that the obtained AD (50th percentile) values of Tc-99m DTPA and F-18 FDG (whole body) were acceptable close agreement with earlier maximum recommended EANM results. However, a significant difference came upon especially for Tc-99m DMSA scan where the minimum activity was 111 MBq contrary to 18 (or 19 MBq) of recommended EANM values.

For pediatrics, there is large variation observed in radioactivity administered. For pediatrics higher administered activity was found than North America [26].

4. Conclusions

Diagnostic reference levels (DRLs), a form of investigation levels, represent an important tool in medical imaging as optimizing the radiation dose delivered to patients. The overall goal is to produce images of improved or comparable image quality while, at the same time reducing the radiation dose to the patient. DRLs provide little incentive for optimization for the 75% of the facilities with doses below the DRL for a particular examination. The achievable dose provides a dose level which is readily achievable by 50% of the facilities. It should be noted that if DRLs are exceeded, a local review of imaging exam procedures and equipment in order to determine whether the protection has been adequately optimized. However, DRLs are not absolute determinants of appropriate use of medical radiation. They are additions to professional judgment that takes the benefits and risks of ionizing radiation for medical imaging into account. DRLs are not regulatory limits or to establish legal standards of care. In addition, DRLs are not applicable to the doses for individual patients. It is essential to ensure that the appropriate clinical information is available in the image throughout the optimization process. In order to implement optimization process, both patient dose and clinical utility must be taken into account depending on image quality.

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