Chapter One

Introduction

1.1 Introduction:

Ionizing radiation has been used in medicine since the discovery of radioactivity and x-rays more than a century ago and is now firmly established as an essential tool for medical diagnosis and therapy. There has been a marked increase in the use of medical x-ray and nuclear imaging in the past decade or so, as new technologies, such as computed tomography and positron emission tomography, have become widespread. These procedures – when medically indicated and properly conducted – provide great benefits to patients; however, the associated radiation exposures have to be monitored and controlled, in view of their potential to cause harmful health effects (Johnson. *et al*, 2000).

In 2008 the European Commission published "Radiation Protection 154: European Guidance on Estimating Population Doses from Medical X-Ray Procedures" (RP 154). The 2008 publication also contained the results of national medical exposure studies in ten European countries. However, a full evaluation of radiation exposure resulting from medical diagnostic procedures in Europe has not been previously carried out. The present report is therefore intended to fill this gap (Johnson. *et al*, 2000).

According to Radiation Protection 109 (EC 1999), Guidance on Diagnostic Reference Levels (DRLs) for Medical Exposures, DRLs should be established both for diagnostic radiology and nuclear medicine, and if they are consistently exceeded, investigation and appropriate corrective action should be taken. Therefore, in diagnostic radiology this level should be higher than the median or mean value of the measured patient doses or doses in a phantom. Locally it is possible to establish DRLs to compare practices in a hospital or between hospitals on a hospital district. Local DRLs should be more stringent or equal to the national or regional DRLs (Johnson. *et al*, 2000).

Ideally, the DRLs should be based on a survey of patient doses, in terms of the same quantity as used for the DRL, in the country, region or hospital where they are to be used as reference values for comparing patient doses determined in the local practice. Therefore, the mean effective doses per x-ray diagnostic procedure, or the mean administered activities per NM procedure, used for the estimation of the collective effective dose to the population in the same country, region or hospital, should on average bear a clear relationship to the corresponding DRL values. Were it not so, it could be an indication of a non-up-to-date DRL or adoption of a generic DRL, which does not reflect the patient dose levels in the real practice of the country, region or hospital (Johnson. *et al*, 2000).

DRLs for several x-ray and NM procedures were collected in the context of the DDM2 questionnaires. This was considered useful because the results of patient dose surveys for the purpose of setting DRLs are often used. The comparison of the DRLs with the mean effective doses used in population dose calculations can provide information for a country to evaluate the appropriateness of the DRLs. For example, if the mean effective dose in a particular procedure is lower than or equal to that in other countries, but the DRL is higher, there may be a need to find out reasons for that and to update DRLs (Johnson. *et al*, 2000).

 "Diagnostic reference levels" means dose levels in medical radio- diagnostic practices or, in the case of radio-pharmaceuticals, levels of activity, for typical examinations for groups of standard-sized patients or standard phantoms for broadly defined types of equipment. These levels are expected not to be exceeded for standard procedures when good and normal practice regarding diagnostic and technical performance is applied(Johnson. *et al*, 2000).

In diagnostic nuclear medicine DRLs are expressed in terms of administered activities (MBq) rather than absorbed dose (2).

The DRL values are not based on the 75th percentile but on the administered activity necessary for a good image on well- adjusted equipment during a standard procedure.

In diagnostic nuclear medicine, while the DRL is not expected to be exceeded in   standard procedures, the DRL should be approached as closely as possible to produce optimized images. As technology improves these DRL values will also need to be adjusted. Over the recent years there have been some surveys of nuclear medicine clinical practice conducted in Irish hospitals.

None of the data derived from these surveys have, as yet, been published in the literature. Practice here closely reflects that in the UK. Therefore it seems reasonable to propose that the UK DRL values, in this specialty, should be used in this country(Johnson.*et al*, 2000).

It should be noted that these DRL values are prescribed for standard sized patients. If the adult patients are of a non-standard size, i.e. less than 50 kg or greater than 90 kg then the injected activities need to be adjusted to allow for this variation. A pro-rata adjustment by patient weight is the simplest method to allow for patient size variation.

A reference group of patients is usually defined within a certain range of physical parameters (e.g. height, weight). If an unselected sample of patients were used as a reference group, it would be difficult to interpret whether the observed value for

the sample is higher or lower than the diagnostic reference level. A diagnostic reference level is not applied to individual patients. The DRL in nuclear medicine is a guidance level for administered activities. It is recommended that this level of activity be administered for a certain type of examination in standard situations. (In diagnostic radiology, if the DRL is consistently exceeded there should be a review or investigation.) In nuclear medicine, for a the recommended amount of administered activity the outcome may be poor. This indicates that the efficacy of gamma cameras, the dose calibration or the procedures used by the staff need to be checked. (In diagnostic radiology, the criterion is normally a satisfactory image. However, the dose needed for this image quality can be too high and, in this case, the radiological equipment should be checked (Johnson. *et al*, 2000).

Use of Diagnostic Reference Levels to Reduce Patient Dose The use of diagnostic reference levels as an important dose optimization tool is endorsed by many professional and regulatory organizations, including the ICRP, American College of Radiology (ACR), American Association of Physicists in Medicine (AAPM), United Kingdom (U.K.) Health Protection Agency, International Atomic Energy Agency (IAEA), and European Commission (EC). Reference levels are typically set at the 75[th]percentile of the dose distribution from a survey conducted across a broad user base (i.e., large and small facilities, public and private, hospital and out-patient) using a specified dose measurement protocol and phantom. They are established both regionally and nationally, and considerable variations have been seen across both regions

and countries . Dose surveys should be repeated periodically to establish new reference levels, which can demonstrate changes in both the mean and standard deviation of the dose distribution.

The use of diagnostic reference levels has been shown to reduce the overall dose and the range of doses observed in clinical practice. For example, U.K. national dose surveys demonstrated a 30% decrease in typical radiographic doses from 1984 to 1995 and an average drop of about 50% between 1985 and 2000 . While improvements in equipment dose efficiency may be reflected in these dose reductions, investigations triggered when a reference dose is exceeded can often determine dose reduction strategies that do not negatively impact the overall quality of the specific diagnostic exam. Thus, data points above the 75 the percentile are, over time, moved below the 75th percentile – with the net effect of a narrower dose distribution and a lower mean dose (Johnson. *et al*, 2000).

1.2 Problem of study:

Most clinical centers of nuclear medicine in Sudan cannot applied diagnostic reference level of doses, and the dose it not constant for patients with same size, gender and Age.

There is no table for the patient's size versus the dose table given which would be used as a baseline or reference for all patients.

1.3 Objectives of Study:

1.3.1 General objective:

The aim of the study is to Establish National Diagnostic Reference Level for Renal Dose in nuclear medicine practice at Alnilain Diagnostic Center and Royal Care International Hospital Nuclear Medicine Department in Sudan.

1.3.2 Specific objective:

- To help avoid radiation dose to the patient that does not contribute to the clinical purpose of a medical imaging task.
- To compare between the numerical value of the diagnostic reference level (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.

- To Optimize the Renal Dose in nuclear medicine department.
- To Investigate for Renal Dose in Alnilain Center and Royal Care Nuclear Medicine Examinations.
- To Determine Exactly the Dose for Renal studies using different variables.
- To establish a local diagnostic reference level (DRL).

.1.11 Research Overview:

The study will be contained in five chapters as follows:

Chapter one is the introduction to this thesis. This chapter discusses the objectives and scope of work and introduces necessary background. It also provides an outline of the thesis.

Chapter two contains the literature review which included the theoretical pervious study.

Chapter three describes the materials and methods used to measure dose for Renal and explain in details the methods used for dose measurement.

Chapter four presents the results of this study. Chapter five presents the discussion, conclusion and recommendations of the thesis.

CHAPTER TWO

Literature Review

2.2 Atomic Structure:

The atom is considered to be the basic building block of all matter. Simple atomic theory tells us that it consists of two components: a nucleus surrounded by an electron cloud. The situation can be considered as being similar in some respects to planets orbiting the sun From an electrical point of view, the nucleus is said to be positively charged and the electrons negatively charged from a size point of view, the radius of an atom is about 10^{-10} m while the radius of a nucleus is about 10^{-14} m, i.e. about ten thousand times smaller. The situation could be viewed as something like a cricket ball, representing the nucleus, in the middle of a sporting arena with the electrons orbiting somewhere around where the spectators would sit. This perspective tells us that the atom should be composed mainly of empty space. However, the situation is far more complex than this simple picture portrays in that we must also take into account the physical forces which bind the atom together. Chemical can be thought of as interactions between the electrons of individual atoms. Radioactivity on the other hand can be thought of as changes which occur within the nuclei of atoms (Kieran. *etal*, 2006).

2.2.1 The Nucleus:

A simple description of the nucleus tells us that it is composed of protons and neutrons. These two particle types are collectively called nucleons, i.e. particles which inhabit the nucleus. From a mass point of view the mass of a proton is roughly equal to the mass of a neutron and each of these is about 2,000 times the mass of an electron. So most of the mass of an atom is concentrated in the small region at its core. From an electrical point of view the proton is positively charged and the neutron has no charge. An atom all on its own (if that were possible to achieve!) is electrically neutral. The number of protons in the nucleus of such an atom must therefore equal the number of electrons orbiting that atom(Kieran. *et al*, 2006).

2.2.2 Classification of Nuclei:

The term Atomic Number is defined in nuclear physics as the number of protons in a nucleus and is given the symbol Z. From your chemistry you will remember that this number also defines the position of an element in the Elements. The term Mass Number is defined as the number of nucleons in a nucleus, that is the number of protons plus the number of neutrons, and is given the symbol A. Note that the symbols here are a bit odd, in that it would prevent some confusion if the Atomic Number were given the symbol A, and the Mass Number were given another symbol, such as M, but its not a simple world! It is possible for nuclei of a given element to have the same number of protons but differing numbers of neutrons that is to have the same Atomic Number but different Mass Numbers. Such nuclei are referred to as Isotopes. All elements have isotopes and the number ranges from three for hydrogen to over 30 for elements such as cesium and barium. Chemistry has a relatively simple way of classifying the different elements by the use of symbols such as H for hydrogen, He for helium and so on. The classification scheme used to identify different isotopes is based on this approach with the use of a superscript before the chemical symbol to denote the Mass Number along with a subscript before the chemical symbol to denote the Atomic Number. In other words an isotope is identified as:

$$_{Z}^{A}X$$

Where X is the chemical symbol of the element; A is the "Mass Number," (protons+ neutrons); Z is the "Atomic Number," (number identifying the element on the periodic chart).

Let us take the case of hydrogen as an example. It has three isotopes:

- the most common one consisting of a single proton orbited by one electron,
- a second isotope consisting of a nucleus containing a proton and a neutron orbited by one electron,
- a third whose nucleus consists of one proton and two neutrons, again orbited by a single electron.A simple illustration of these isotopes is shown below. Remember though that this is a simplified illustration given what we noted earlier about the size of a nucleus compared with that of an atom. But the illustration is nevertheless useful for showing how isotopes are classified.
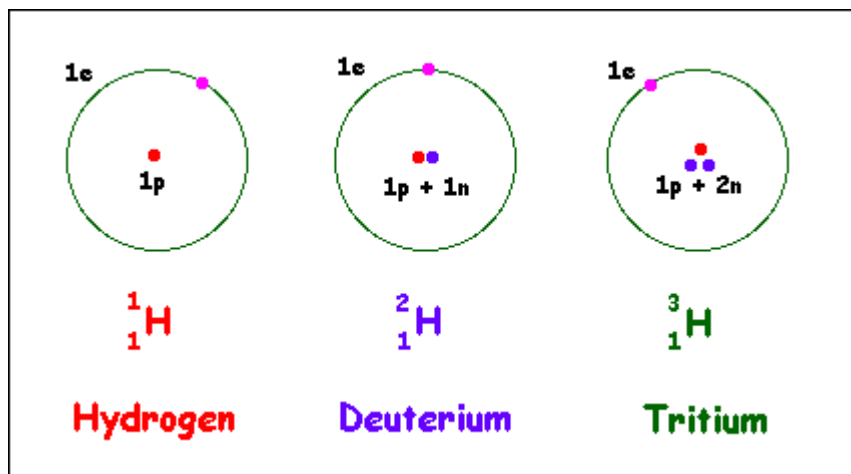
1.2 figures shows the mass number and atomic number of hydrogen, deuterium and tritium

The first isotope commonly called hydrogen has a Mass Number of 1, an Atomic Number of 1 and hence is identified as:

$${}^{1}_{1}\textbf{H}$$

The second isotope commonly called deuterium has a Mass Number of 2, an Atomic Number of 1 and is identified as:

$${}^{2}_{1}\textbf{H}$$

The third isotope commonly called tritium is identified as:

$${}^{3}_{1}\textbf{H}$$

The same classification scheme is used for all isotopes. For example, you should now be able to figure out that the uranium isotope, ${}^{236}_{92}\textbf{U}$, contains 92 protons and 144 neutrons.

A final point on classification is that we can also refer to individual isotopes by giving the name of the element followed by the Mass Number. For example, we can refer to deuterium as hydrogen-2 and we can refer to ${}^{236}_{92}\textbf{U}$ as uranium-236.

Before we leave this classification scheme let us further consider the difference between chemistry and nuclear physics. You will remember that the water molecule is made up of two hydrogen atoms bonded with an oxygen atom. Theoretically if we were to combine atoms of hydrogen and oxygen in this manner many, many of billions of times we could make a glass of water. We could also make our glass of water using deuterium instead of hydrogen. This second glass of water would theoretically be very similar from a chemical perspective. However, from a physics perspective our second glass would be heavier than the first since each deuterium nucleus is about twice the mass of each hydrogen nucleus. Indeed water made in this fashion is called heavy water(Kieran .etal 2006).

2.2.3 Atomic Mass Unit:

The conventional unit of mass, the kilogram, is rather large for use in describing characteristics of nuclei. For this reason, a special unit called the Atomic Mass Unit (amu) is often used. This unit is sometimes defined as 1/12th of the mass of the stable most commonly occurring isotope of carbon, i.e. ^{12}C. In terms of grams, 1 amu is equal to 1.66×10^{-24} g, that is, just over one million, million, million millionth of a gram.

The masses of the proton, m_p and neutron, m_n on this basis are:

$m_p = 1.00783$ amuand$m_n = 1.00866$ amu

While that of the electron is just 0.00055 amu(Kieran .*etal* 2006).

2.2.4 Nuclear Binding Energy:
According to the classical electrostatic theory, the nucleus of an atom cannot exist as a single entity, because of the electrostatic repulsive force among the protons in the nucleus. The stability of the nucleus is explained by the existence of a strong binding force called the nuclear force, which overcomes the repulsive force of the protons. The nuclear force is effective equally among all nucleons and exists only in the nucleus, having no influence outside the nucleus. The short range of the nuclear force leads to a very small size (~10−13 cm) and very high density (~1014g/cm3) of the nucleus. The mass M of a nucleus is always less than the combined masses of the nucleons A in the nucleus. The difference in mass (M − A) is termed the mass defect,

which has been used as binding energy for all nucleons in the nucleus. The average binding energy of a nucleon is equal to the total binding energy (calculated from the mass defect) divided by the number of nucleons. It is of the order of 6–9MeV, although the binding energy of an individual nucleon has a definite value, depending on the shell it occupies. The binding energy of a nucleon must be supplied to completely remove it from the nucleus(Saha, 2006).

2.2.5 Nuclear Stability:

In most stable isotopes the binding energy per nucleon lies between 7 and 9 MeV. There are two competing forces in the nuclei, electrostatic repulsion between protons and the attractive nuclear force between nucleons (protons and neutrons). The electrostatic force is a long range force that becomes more difficult to compensate for as more protons are added to the nucleus. The nuclear force, which arises as the residual strong force (the strong force binds the quarks together within a nucleon), is a short range force that only operates on a very short distance scale (~ 1.5 FM) as it arises from a Yukawa potential. (Electromagnetism is a long range force as the force carrier, the photon, is mass less; the nuclear force is a short range force as the force carrier, the pion, is massive). Therefore, larger nuclei tend to be less stable, and require a larger ratio of neutrons to protons (which contribute to the attractive strong force, but not the long-range electrostatic repulsion). For the low Z nuclides the ratio of neutrons to protons is approximately 1, though it gradually increases to about 1.5 for the higher Z nuclides as shown below on the Nuclear Stability Curve (Kieran .etal 2006).
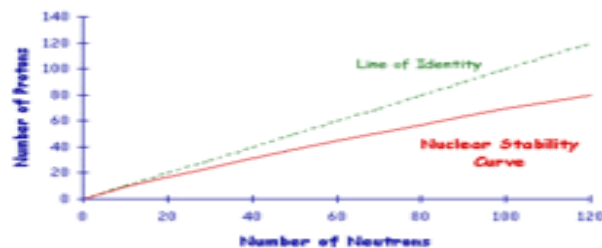
2.2 figures shows the nuclear stability curve

In other words to combat the effect of the increase in electrostatic repulsion when the number of protons increases the number of neutrons must increase more rapidly to contribute sufficient energy to bind the nucleus together. As we noted earlier there are a number of isotopes for each element of the Periodic Table. It has been found that the most stable isotope for each element has a specific number of neutrons in its nucleus. Plotting a graph of the number of protons against the number of neutrons for these stable isotopes generates what is called the Nuclear Stability Curve: Note that the number of protons equals the number of neutrons for small nuclei. But notice also that the number of neutrons increases more rapidly than the number of protons as the size of the nucleus gets bigger so as to maintain the stability of the nucleus. In other words more neutrons need to be there to contribute to the binding energy used to counteract the electrostatic repulsion between the protons(Kieran .etal 2006).

2.3 Radioactivity:

There are about 2,450 known isotopes of the approximately one hundred elements in the Periodic Table. You can imagine the size of a table of isotopes relative to that of the Periodic Table! The unstable isotopes lie above or below the Nuclear Stability Curve. These unstable isotopes attempt to reach the stability curve by splitting into fragments, in a process called Fission, or by emitting particles and/or energy in the form of radiation. This latter process is called Radioactivity. It is useful to dwell for a few moments on the term radioactivity. For example what has nuclear stability to do with radio? From a historical perspective remember that when these radiations were discovered about 100 years ago we did not know exactly what we were dealing with. When people like Henri Becquerel and Marie Curie were working initially on these strange emanations from certain natural materials it was thought that the radiations were somehow related to

anotherphenomenon which also was not well understood at the time - that of radio communication. It seems reasonable on this basis to appreciate that some people considered that the two phenomena were somehow related and hence that the materials which emitted radiation were termed radio-active (Saha, 2006).

We know today that the two phenomena are not directly related but we nevertheless hold onto the term radioactivity for historical purposes. But it should be quite clear to you having reached this stage of this chapter that the term radioactive refers to the emission of particles and/or energy from unstable isotopes. Unstable isotopes for instance those that have too many protons to remain a stable entity are called radioactive isotopes - and called radioisotopes for short. The term radionuclide is also sometimes used (Saha, 2006).

Finally about 300 of the 2,450-odd isotopes mentioned above are found in nature. The rest are man-made, that is they are produced artificially. These 2,150 or so artificial isotopes have been made during the last 100 years or so with most having been made since the Second World War. We will return to the production of radioisotopes in a later chapter of this wiki book and will proceed for the time being with a description of the types of radiation emitted by radioisotopes(Kieran .etal 2006).

2.3.1 Methods of Radioactive Decay:

Rather than considering what happens to individual nuclei it is perhaps easier to consider a hypothetical nucleus that can undergo many of the major forms of radioactive decay. This hypothetical nucleus is shown below:
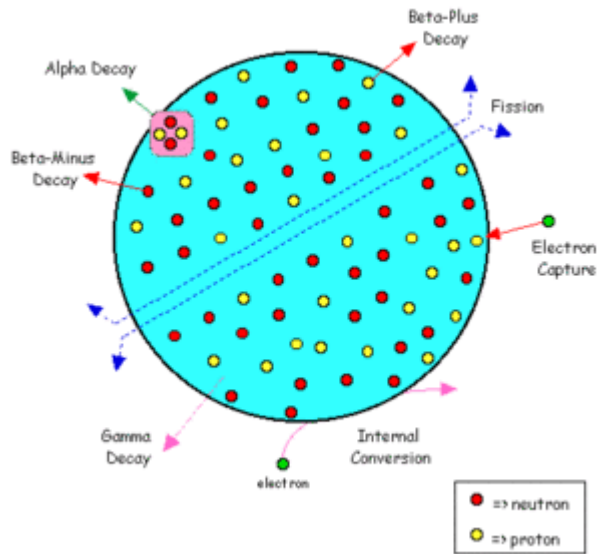
3.2 figures shows the hypothetical of nucleus

A hypothetical nucleus which can undergo many forms of radioactive decay firstly we can see two protons and two neutrons being emitted together in a process called alpha-decay. Secondly, we can see that a proton can release a positron in a process called beta-plus decay, and that a neutron can emit an electron in a process called beta-minus decay. We can also see an electron being captured by a proton. Thirdly we can see some energy (a photon) being emitted which results from a process called gamma-decay as well as an electron being attracted into the nucleus and being ejected again. Finally there is the rather catastrophic process where the nucleus cracks in half called spontaneous fission. We will now describe each of these decay processes in turn (Kieran .etal,2006).

2.3.2 Spontaneous Fission:

This is a very destructive process which occurs in some heavy nuclei which split into 2 or 3 fragments plus some neutrons. These fragments form new nuclei which are usually radioactive. Nuclear reactors exploit this phenomenon for the production of radioisotopes. It's also used for nuclear power generation and in nuclear weaponry. The process is not of great interest to us here and we will say no more about it for the time being (Kieran .etal 2006).

2.3.3 Alpha Decay:

Usually heavy nuclei such as radon, uranium, neptunium, and so forth decay by a-particle emission. The (a) particle is a helium ion with two electrons stripped off the atom and contains two protons and two neutrons bound together in the nucleus. In (a) decay, the atomic number of the parent nuclide is therefore reduced by 2 and the mass number by 4. A transition may be followed by b emission or g-ray emission or both. The a particles are monoenergetic, and their range in matter is very short (on the order of 10 6 cm) and is approximately 0.03 mm in body tissue(Saha, 2010).

2.3.4 Beta Decay:

When a nucleus is "neutron rich" (i.e., has a higher N/Z ratio compared to the stable nucleus), it decays by (b) particle emission along with an antineutrino. An antineutrino (v) is an entity almost without mass and charge and is primarily needed to conserve energy in the decay. In (b) decay, a neutron (n) essentially decays into a proton (p) and a (b) particle, the (b) particle is emitted with variable energy from zero up to the decay energy. The decay or transition energy is the difference in energy between the parent and daughter nuclides. An antineutrino carries away the difference between the (b) particle energy and the decay energy. The (b) decay may be followed by g-ray emission, if the daughter nuclide is in an excited state and the number of g rays emitted depends on the excitation energy. After (b)decay, the atomic number of the daughter nuclide is one more than that of the parent nuclide; however, the mass number remains the same for both nuclides (Saha, 2010).

2.3.5 Gamma Decay:

Radioactive decay often results in the formation of a daughter nucleus in an excited state. The EM radiation emitted from the nucleus as the excited state decays to a lower (more stable) energy state is called a gamma ray. This energy transition is analogous to the emission of characteristic x-rays following electron transition. However, gamma rays (by definition), emanate from the nucleus. Because the spacing of the energy states within the nucleus is often considerably larger than those associated with electron transitions, gamma rays are often much more energetic than characteristic x-rays. When this nuclear de-excitation process takes place in a metastable isomer (e.g., Tc-99m), it is called isomeric transition (Saha, 2010).

2.3.6 Radiation dose from imaging examinations:

Because the doses of radiotracer administered are small, diagnostic nuclear medicine procedures result in relatively low radiation exposure to the patient, acceptable for diagnostic exams. Thus, the radiation risk is very low compared with the potential benefits.

- Nuclear medicine diagnostic procedures have been used for more than five decades, and there are no known long-term adverse effects from such low-dose exposure.
- The risks of the treatment are always weighed against the potential benefits for nuclear medicine therapeutic procedures. You will be informed of all significant risks prior to the treatment and have an opportunity to ask questions.
- Allergic reactions to radiopharmaceuticals may occur but are extremely rare and are usually mild. Nevertheless, you should inform the nuclear medicine personnel of any allergies you may have or other problems that may have occurred during a previous nuclear medicine exam.
- Injection of the radiotracer may cause slight pain and redness which should rapidly resolve.
- Women should always inform their physician or radiology technologist if there is any possibility that they are pregnant or if they are breastfeeding.

A useful way to understand radiation doses from diagnostic examinations is to compare them to average natural background radiation (3 mSv per year) Radiation doses are sometimes expressed as entrance skin doses. Entrance skin doses are used in conventional radiography: a dose estimate at 1 point in the beam allows estimates of organ doses and effective dose. To assess the health risks of low doses of ionizing radiation, the International Commission on Radiation Protection uses the concept of effective dose.[5] The effective dose is not measured but is a theoretical calculated dose based on the organs exposed by the applied radiation multiplied by tissue-weighting factors. Because the tissue-weighting factors can change with new data and continuing analysis of existing data, the effective dose estimates can change over time. It should be noted that dose estimates are generally given for an adult of typical size and may vary substantially depending on patient size and imaging technique. Effective dose estimates are best used to assess the general level of radiation risk and not to determine the exact radiation dose

from an imaging study. Effective dose estimates for individual patients are subject to a substantial level of uncertainty (Peter. *etal*, 2005).

2.3.7 The benefits of nuclear medicine examinations:

- Nuclear medicine examinations provide unique information including details on both function and anatomic structure of the body that is often unattainable using other imaging procedures.

- For many diseases, nuclear medicine scans yield the most useful information needed to make a diagnosis or to determine appropriate treatment, if any.

- Nuclear medicine is less expensive and may yield more precise information than exploratory surgery.

- Nuclear medicine offers the potential to identify disease in its earliest stage, often before symptoms occur or abnormalities can be detected with other diagnostic tests.

- By detecting whether lesions are likely benignor malignant, PET scans may eliminate the need for surgical biopsy or identify the best biopsy location.

- PET scans may provide additional information that is used for radiation therapy planning (Wall B.F June 2004).

- **2.3.8 Pervious study**

.GökçeKaanAtaç et al, 2015

They aimed to establish the first diagnostic reference levels (DRLs) for computed tomography (CT) examinations in adult and paediatric patients in Turkey and compare these with international DRLs. CT performance information and examination parameters (for head, chest, high-resolution CT of the chest [HRCT-chest], abdominal, and pelvic protocols) from 1607 hospitals were collected via survey. Dose length products and effective doses for standard patient sizes were calculated from the reported volume CT dose index (CTDIvol). The median number of protocols reported from the 167 responding hospitals (10% response rate) was 102 across five different age groups. Third quartile CTDI values for adult pelvic and all paediatric body protocols were higher than the European Commission standards but were comparable to studies conducted in other countries vole.The radiation dose indicators for adult patients were similar to those reported in the literature, except for those associated with head protocols. CT protocol optimization is necessary for adult head and paediatric chest, HRCT-chest, abdominal, and pelvic protocols. The findings from this study are recommended for use as national DRLs in Turkey.

. Niksiratet al, Jan 2016:

This study conducted a review on nuclear medicine (NM) services in Mazandaran Province
With a view to establish adult diagnostic reference levels (DRLs) and provides updated data on population radiation exposure resulting from diagnostic NM procedures.

The data were collected from all censers in all cities of Mazandaran Province in the North of Iran from March 2014 to February 2015. The 75th percentile of the distribution and the average administered activity (AAA) were calculated and the average effective dose per examination, collective effective dose to the population and annual effective dose per capita were estimated using dose conversion factors. The gathered data were analysed via SPSS (version 18) software using descriptive statistics. Based on the data of this study, the collective effective dose was 95.628 mSv, leading to a mean effective dose of 0.03 mSv per capita. It was also observed that the myocardial perfusion was the most common procedure (50%). The 75th percentile of the distribution of administered activity (AA) represents the DRL. The AAA and the 75th percentile of the distribution of AA are slightly higher than DRL of most European countries. Myocardial

perfusion is responsible for most of the collective effective dose and it is better to establish national DRLs for myocardial perfusion and review some DRL values through the participation of NM specialists in the future. Keywords: Collective effective dose, diagnostic reference levels, nuclear medicine, radiation exposure.

. Hiroshi Watanabe et al, 2014:

The optimization of medical exposure is one of the major issues regarding radiation protection in the world, and The International Committee of Radiological Protection and the International Atomic Energy Agency recommend establishing diagnostic reference levels (DRLs) as tools for dose optimization. Therefore, the development of DRLs based on the latest survey has been required for nuclear medicine-related societies and organizations. This prompted us to conduct a nationwide survey on the actual administered radioactivity to adults for the purpose of developing DRLs in nuclear medicine. A nationwide survey was conducted from November 25, 2014 to January 16, 2015. The questionnaire was sent to all of the 1249 nuclear medicine facilities in Japan, and the responses were collected on a website using an answered form. Responses were obtained from 516 facilities, for a response rate of 41 %. 75th percentile of 99mTc-MDP   and 99mTc-HMDP: bone   scintigraphy, 99mTc-HM-PAO, 99mTc-ECD and 123I-IMP: cerebral blood flow scintigraphy, 99mTc-Tetrofosmin, 99mTc-MIBI and 201Tl-Cl; myocardial perfusion scintigraphy and18F-FDG: oncology PET (in-house-produced or delivery) in representative diagnostic nuclear medicine scans were 932, 937, 763, 775, 200, 831, 818, 180, 235 and 252, respectively. More than 90 % of the facilities were within the range of 50 % from the median of these survey results in representative diagnostic nuclear medicine facilities in Japan. Responses of the administered radio activities recommended by the package insert, texts and guidelines such as 740 MBq (99mTc-MDP and 99mTc-HMDP: bone scintigraphy), 740 MBq (99mTc-ECD and 99mTc-HM-PAO: cerebral blood flow scintigraphy) and 740 MBq (99mTc-Tetrofosmin and 99mTc-MIBI: myocardial perfusion scintigraphy), etc. were numerous. The administered activity of many radiopharmaceuticals of bone scintigraphy (99mTc-MDP and 99mTc-HMDP), cerebral blood flow scintigraphy (99mTc-HM-PAO) and myocardial perfusion scintigraphy (99mTc-Tetrofosmin and 99mTc-MIBI), etc. were within the range of the EU DRLs and almost none of the administered radioactivity in Japan exceeded the upper limit of SNMMI standard administered radioactivity. This survey indicated that the administered radioactivity in diagnostic nuclear medicine in Japan had been in the convergence

zone and nuclear medicine facilities in Japan show a strong tendency to adhere to the texts and guidelines. Furthermore, the administered radio activities in Japan were within the range of variation of the EU and the SNMMI administered radioactivity's.

Chapter three

Material and mathods

This is a community based descriptive study. Specially designed to establish the anatomical and physiology variation of normal renal system among adult Sudanese patients using gamma camera.

3.1 Materials:

3.1.1 Machine used:

3.1.2 Study area and duration:

The study was take place in Khartoum state in Royal Care International Hospital and Alnilain Medical Diagnostic Center.

The study was conducted during the period six month.

Gamma camera: machine type is nucline sprite (DHV) class 1, type B equipment medical diagnostic , serial number is DH-004467-OV manufactured in 2010 made in Hungary.

dose calibrators, radiopharmaceutical, syringe, dose (activity) range is vary between (2.8-6.5 mci), scan time is 30 mint.

Dose calibrators in Alnilain Medical Diagnostic Center establish in 2006, and Royal Care International Hospital establish in 2012.

3.2 Methods:

3.2.1 Study population:

(111) Sudanese adult patients ("52" males, "59" females), patients age range between (18-85 years) free from any Renal disease that affect the measurements of uptake under went to gamma camera scan.

3.3 Patient preparation:

.Little patient preparation was required for a gamma camera but the following points should be noted:-

.The technician explained the procedure to the patient briefly before examinations.

.The patient should drinks more water and pass away be for the examination.

If the patient was comfortable on the table the result was less motion and therefore less degradation of image quality.

3.3.1 Patient positioning:-

The patient was in supine position and the head of gamma camera sometimes over couch and sometimes under couch.

3.3.2 Interviewing of patient:-

Concerned with revision of their referred notes, measuring of body weight to the nearest kilogram, patient height to the nearest centimeter and ask the patient about his, her age.

3.4 Method of Data analysis:-

The data was collected on a master sheet design for that purpose, different tables used to tabulate the finding which were statically analyzed using Spss.

Chapter Four

Results

Results

Table 4.1 demographic data for all patients and patients dose in mCi at NMDC.

	Mean	STD	Min	Max
Age	45.63	16.44	18	80
High	1.61	0.105	1.40	1.95
Weight	64.35	15.03	35	105
BMI	24.66	5.48	13.67	44.85
Dose	4.96	0.303	3.50	5.60

Table 4.2 demographic data for Female and patients' dose in mCi at NMDC.

	Mean	Median	STD	Min	Max
Age	43.04	42	12.64	21	70
High	158.67	158	9.39	140	180
Weight	64.07	64	14.69	41	105
dose	4.77	5	0.79	2.8	6.3

Table 4.3 demographic data for Male and patients' dose in mCi at NMDC.

	Mean	Median	STD	Min	Max
Age	51.42	58.50	18.79	18	80
High	165.63	165	8.17	150	182
Weight	64.46	64.5	12.18	46	85
Dose	4.87	5	0.60	3.9	6.3

Table 4.4 demographic data for all patients and patients dose in mCi at RCIH.

	Mean	STD	Min	Max
Age	46.98	16.23	18	80
High	1.61	0.094	1.4	1.82
Weight	64.25	13.43	41	105
BMI	24.60	5.47	17.26	44.85
Dose	4.82	0.70	2.80	6.30

Table 4.5 demographic data for Female and patients' dose in mCi at RCIH.

	Mean	Median	STD	Min	Max
Age	41.97	41	13.72	21	70
High	157.13	155	8.99	140	185
Weight	62.72	63.5	15.53	35	105
Dose	4.91	5	0.317	3.5	5.1

Table 4.6 demographic data For Male and patients' dose in mCi at RCIH.

	Mean	Median	STD	Min	Max
Age	49.82	53	18.46	18	80
High	166.46	165	10.09	150	195
Weight	66.21	67.5	14.5	35	97
dose	5.01	5	0.28	4	5.6

Table 4.7 show statistical parameters for patient's dose in mCi at NMDC and RCIH.

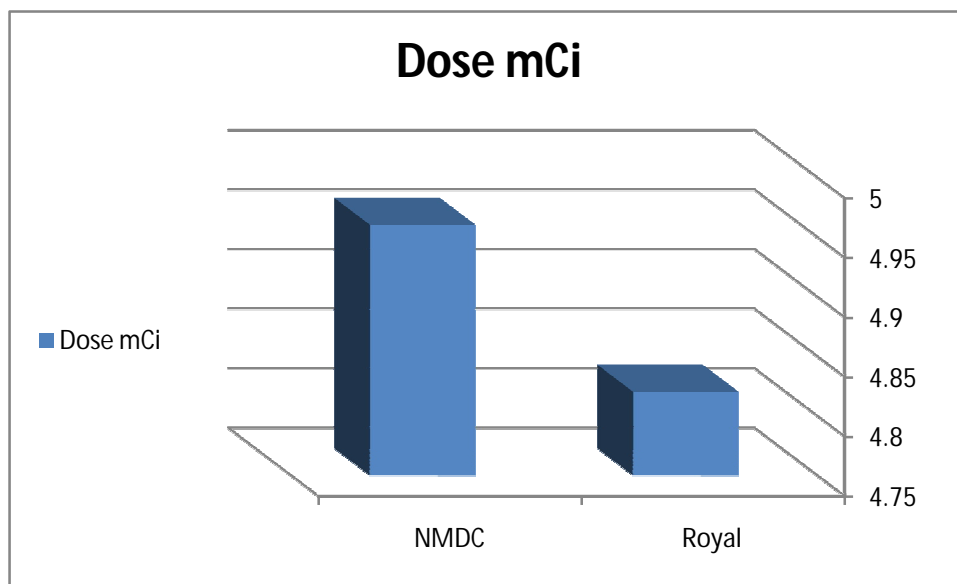|	Mean	STD	Min	Max
Royal	4.82	0.70	2.80	6.30
NMDC	4.96	0.303	3.50	5.60

Figure 4.1 show statistical parameters for patient's dose in mCi at NMDC and RCIH.

Chapter Five

Discussion, Conclusion and Recommendation

5.1 DISCUSSION:

Establishment of National Diagnostic Reference Level for Renal Doses in Alnilain Diagnostic Center and Royal Care International Hospital Nuclear Medicine Department

The data in this research is collected form 111 patients who were selected from two hospitals, who were diagnosed in royal care international hospital (51) patients and Alnileen diagnostic medical center (60) patients in nuclear medicine departments and the data represented in tables and figure.

In Table 4.1 show statistical parameter for all patients (51) and the variable s was age , high, weight, body mass Index and the dose(activity) and the values was mean ± STD age (45.63±16.44), high(1.61±0.105), weight(64.35±15.03),

Table 4.2 show statistical parameter for female(27) and the variable s was age , high, weight, body mass Index and the dose(activity) and the values was {mean ± STD age (43.04±12.64), high(158.67±9.39), weight(64.07±14.69), Dose (4.77±0.79)

Table 4.3 show statistical parameter for male(24) and the variable s was age , high, weight, body mass Index and the dose(activity) and the values was {mean ± STD} age (51.42±18.79), high(165.63±8.17), weight(64.46±12.18), Dose(4.87±0.60)

Secondly for royal hospital

Table 4.4 show statistical parameter for all patents (60) and the variable s was age , high, weight, body mass index and the dose(activity) and the values was{mean ± STD} age (46.98±16.23), high(1.61±0.094), weight(64.25±13.43), BMI(24.60±5.47) Dose(4.82±0.70)

Table 4.5 show statistical parameter for male(23) and the variable s was age , high, weight, body mass index and the dose(activity) and the values was {mean ± STD} age (49.82±18.46), high(166.46±10.09), weight(66.21±14.5), Dose(5.01±0.28)

Table 4.6 show statistical parameter for female(28) and the variable s was age , high, weight, body mass index and the dose(activity) and the values was {mean ± STD} age (41.97±13.72), high(157.13±8.99), weight(62.72±15.53), Dose(4.91±0.317)

Table 4.7 show the statistical parameter of dose (activity) for all centers and the values was {mean ± STD} royal (4.82±0.70), Alnileen(4.96±0.303)

Figure 4.1 show the compare for Dose per mCi in NMDC and RCIH where it's higher in NMDC (4.95) than RCIH (4.82) mCi.

Figure 1 compares the activity in mCi between the two hospitals and the results appeared clearly that NMDC (4.96) higher than RCIH 4.82. figure 2 show dose distribution which is divided for patients to three groups, the first group received dose less than 5 mCi are represent (27.03 %) from all patients, second group received dose 5 to 5.5 mCi are represent (66.67 %) and the third group received dose from 5.6 to 6.2 mCi are represent (6.31 %) from all patients ^{99m}Tc-DTPA.

5.2 Conclusion:

The study was carried out in order to establishment diagnostic reference level for dose (activity) for diagnostic renal system.

The data of this study collected form (111) patients in NMDC and RCIH, In order to evaluate the radiological risk incurred by patients diagnosed at the Department of Nuclear Medicine (DNM). The high specific activity of ^{99m}Tc makes it suitable as a first pass agent, for multiple or sequential studies, ^{99m}Tcdiethylenetriaminepentaacetic acid (DTPA) is preferred to ^{99m}Tcpertechnetate. DTPA has rapid renal excretion, making possible a repeat injection 20 min later. Technetium-99m pertechnetate can be used when a single assessment of ventricular function is needed.

5.3 Recommendations:

1- Qualification of the nuclear medicine staff properly.

2- Conducting renal imaging on additional nuclear medicine centers and larger number of patients in order to have more reliable results.

3- Establishment of more effective radiation protection systems at the nuclear medicine department in Sudan.

4- Future studies could include similar measurements on other body organs.

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