Sudan University of Sciences & Technology

College of Graduate Studies

Evaluation of Radiation Dose in Nuclear Medicine Departments in Khartoum state

تقويم الجرعات الإشعاعية في أقسام الطب النووي فى ولاية الخرطوم

A Thesis Submitted for Partial Fulfillment of M.sc Degree in Medical physics

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الآية

قال تعالى:

(ن وَالْقَلَمِ وَمَا يَسْطُرُونَ)

صدق الله العظيم

سورة القلم الآية (1)

Dedication

To

My parents...

My friends

And to all people who stood side by side with me,

I dedicate this humble work.

Acknowledgement

I would like to express my deep gratitude to my supervisor Dr. **Salah Ali Fadlalla** for his invaluable guidance, fruitful instructions and comments throughout this work.

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Abstract

This study was conducted in Al-Nilain center and Royal Care Hospital in Khartoum state during the period (July-September, 2018). The main objective of the study was to evaluate the radiation dose in nuclear medicine departments in the above mentioned centers.

The researcher used a survey meter to evaluate the level of radiation in all rooms that contain radiation in the two centers namely, (Hot lab room, waiting room, injection room and imaging room). The new (SI) units were used for the measurements.

It was noticed that the level of radiation in the waiting room and the injection room at the two departments was within the range accepted by the international organizations. As for the preparation room, and the imaging room the radiation doses were relatively high. This may be due to the fact that the preparation room is the place in which the radioactive materials which are injected to the patients are prepared. As for the imaging room, it is the place where the patients are received for imaging, and the patients constitute a source of radiation.

The study showed that the two centers under study were similar in the level of the radiation dose according to the international standards.

The study proposed some recommendations which could be useful, including the importance of using modern radiation measurement and control devices to measure personal radiation doses, and increasing the number of nuclear medicine departments in Sudan.

المستخلص

أجريت هذه الدراسة بمركز النيلين التشخيصي ومستشفى رويال كير فى ولاية الخرطوم خلال الفترة (يونيو–سبتمبر 2018م) وكان الهدف الرئيسي من الدراسة هو تقويم الجرعات الاشعاعية في قسمى الطب النووي.

استخدمت الدارسه جهاز المسح الاشعاعي لتقويم الاشعاع في كل غرفه يوجد بها اشعاع في كلا المركزين واستخدمت الوحدات الحديثة للقياس والغرف هى غرفة التحضير، غرفة الانتظار، غرفة الحقن وغرفة التصوير.

ولوحظ إن مستوى الإشعاع في غرفة الانتظار وغرفة الحقن في كلا القسمين يدخل في اطار المستوى المسموح به عالميا. أما في غرفة التحضير وغرفة التصوير كانت الجرعات الاشعاعيه كبيرة نوعاً ما ويعزى السبب في ذلك الى أن غرفة التحضير هي غرفة تجهيز وتحضير المادة المشعة المراد حقنها للمريض. أما غرفة التصوير فهى تستقبل الإشعاع من المريض لأن المريض في هذه الحالة مصدر اشعاعى نتيجة حقنه بالمادة المشعة.

يتشابه كلا المركزين في كمية الإشعاع وفقا للمستويات العالميه للحماية من الإشعاع.

اقترحت الدراسة بعض التوصيات منها أن تستخدم اجهزة قياس اشعاعية حديثه مع زيادة اقسام الطب النووي في السودان وأن تكون هنالك أجهزة قياس وضبط للإشعاع لكل فرد في اقسام الطب النووي.

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List of abbreviations:

CT	Computed Tomography
MIBG	Meta Iodo Benzyl Guanidine
MRI	Magnetic Resonance Imaging
PET	Positron Emission Tomography
SPECT	Single Photon Emission Computed Tomography
SPSS	Statistical Package for Social Science

Chapter One

Introduction

Chapter One

1.1 Introduction:

Nuclear medicine has played a significant role in clinical medicine since early 1960s.

Some of the greatest changes in the working, pattern of clinical services have been brought about, by the development of new radiopharmaceutical, the best. Known example is the Introduction of Tc99m.labeled bone imaging agents in the early 1970s. However the development of radiopharmaceutical is slow and expensive (Dister, 1998).

1.2 Nuclear medicine Definition:

Nuclear medicine is a medical specialty involving the application of radioactive substances in the diagnosis and treatment of disease. Nuclear medicine, is"radiology done inside out" or "end radiology" because it records radiation emitting from within the body rather than radiation that is generated by external sources like X–rays. In addition, nuclear medicine

Scans differ from radiology as the emphasis is not on imaging anatomy but the function and for such reason; it is called a physiological imaging modality. Single photon Emission Computed Tomography or SPECT and Positron Emission Tomography or PET scans are the two most common imaging modalities in nuclear medicine (Dister, 1998).

Nuclear medicine is the branch of medicine that involves the administration of radioactive substances in order to diagnose and treat disease. The scenes performed in nuclear medicine are carried out by a radiographer. This specialty of nuclear medicine is sometimes referred to as end radiology because the radiation emitted from inside the body is detected rather than being applied externally, as with and X –rays procedure, for example.

For nuclear medicine scans, radionuclides are combined with other chemical compounds to for the radiopharmaceutical that are widely used in this field.

When administered to the patient, these radiopharmaceutical target specific organs ore cellular receptors and bind to them selectively. External detectors are used to capture the radiation emitted from

The radiopharmaceutical as it moves through the body and this is used to generate an image.

Diagnosis is based on the way the body is known to handle substances used in the health state disease state (Donald, 1997).

The radionuclide e used is usually bound to a specific complex (tracer) that is known to act in a particular way in the body. When disease is present, the tract may be distributed or processed in a different way no disease is present. Increased physiology function that may occur as result of disease or injury usually in an increased concentration of the tracer, which can often be detected as a" hot spot." sometimes, the disease process leads to exclusion of the tracer and a "cold spot" is detected instead .A large variety of tracer complexes are used in nuclear medicine to visualize and treat the different organs, tissues and physiological system the body.

The main difference between nuclear medicine diagnostic tests and other imaging modalities is that nuclear imaging techniques show the physiological function of tissue or organ being investigated, while traditional imaging system such as computed tomography (CT scan)

And magnetic resonance imaging (MRI scan) show only the anatomy or structure.

Nuclear medicine imaging techniques are also organ or tissue specific while a CT or MRI scan can be used to visualize the whole of the chest cavity or abdominal cavity, for example nuclear imaging techniques are used to view specific organs such as the lungs, heart or brain. Nuclear medicine studies can also be whole – body, if the agent used targets specific cellular receptors or function .Examples of these techniques include the whole – body PET scan or

PET/CT scan, the Meta iodo benzyl guanidine (MIBG) scan, the octreotide scan, the indium white blood cell scan, and the gallium scan (O.ALI, 2001).

Nuclear medicine uses radioactive isotopes in a variety of ways. One of the more common uses is as a tracer in which a radioisotope, such as technetium-99m, is taken orally or is injected or is inhaled into the body. The radioisotope then circulates through the body or is taken up only by certain tissues. Its distribution can be tracked according to the radiation it gives off. The emitted radiation can be captured by various imaging techniques, such as single photon emission computed tomography (SPECT) or positron emission tomography (PET), depending on the radioisotope used. Through such imaging, physicians are able to examine blood flow to specific organs and assess organ function or bone growth. Radioisotopes typically have short half-lives and typically decay before their emitted radioactivity can cause damage to the patient’s body.

Therapeutic applications of radioisotopes typically are intended to destroy the targeted cells. This approach forms the basis of radiotherapy, which is commonly used to treat cancer and other conditions involving abnormal tissue growth, such as hyperthyroidism. In radiation therapy for cancer, the patient’s tumor is bombarded with ionizing radiation, typically in the form of beams of subatomic particles, such as protons, neutrons, or alpha or beta particles, which directly disrupt the atomic or molecular structure of the targeted tissue. Ionizing radiation introduces breaks in the double-stranded DNA molecule, causing the cancer cells to die and thereby preventing their replication. While radiotherapy is associated with unpleasant side effects, it generally is effective in slowing cancer progression or, in some cases, even prompting the regression of malignant disease.

The use of radioisotopes in the fields of nuclear medicine and radiotherapy has advanced significantly since the discovery of artificial radioisotopes in the first decades of the 1900s. Artificial radioisotopes are produced from stable elements that are bombarded with neutrons. Following that discovery, researchers began to investigate potential medical applications of artificial radioisotopes, work that laid the foundation for nuclear medicine. Today diagnostic and therapeutic procedures using radioactive isotopes are routine.

1.3 Problem of the study:

There is no regular evaluations of radiation dose in the two centers, to the best of the researcher's knowledge. This may lead to unknown amounts of radiation doses and risks to the staff and other people.

1.4 Objectives of the study:

1.4.1 The general objective:

To evaluate the radiation dose in nuclear medicine departments in royal care hospital and Aniline medical center

1. 4.2 The specific objectives:

To evaluate the radiation dose in hot laboratory.

To evaluate the radiation dose in injection room.

To evaluate the radiation dose in waiting room.

To evaluate the radiation dose in gamma camera room.

To compare the result with the international standards.

1.5 Materials and methods:

1.5.1 Materials:

Survey monitor (RDS - 120 universal survey meter) RADOS.

1.5.2 Methods:

1.5.2.1 Methods of Date Collection:

Textbooks, Internet, Previous studies

1.5.2.2 Methods of Date Analysis:

Qualitative and quantitative description and statistical methods included arithmetic means, standard deviation for significant purpose. in addition to the SPSS program.

1.6 Place and duration of the Study:

The study was conducted at Al-nilain and Royal Care nuclear medicine departments, during the period from July to September2018.

1.7 Content of the study:

This study included five chapters, as follows:-

Chapter one: Introduction

Is an introduction of the theoretical framework of the study, the chapter presented the statement of the problem of the study, objective of the study, and methodology.

Chapter two: Literature Review

2.1 Theoretical background

2.2 Previous Studies

Chapter three: Materials and methods.

Chapter Four: The results

Chapter Five: Discussion, conclusion and recommendations

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Chapter Two

Literature Review

2.1. Theoretical Background

2.1.1 General Nuclear Medicine

Nuclear medicine is a branch of medical imaging that uses small amounts of radioactive material to diagnose and determine the severity of or treat a variety of diseases, including many types of cancers, heart disease, gastrointestinal, endocrine, neurological disorders and other abnormalities within the body. Because nuclear medicine procedures are able to pinpoint molecular activity within the body, they offer the potential to identify disease in its earliest stages as well as a patient's immediate response to therapeutic interventions.

Diagnosis: Nuclear medicine imaging procedures are noninvasive and, with the exception of intravenous injections, are usually painless medical tests that help physicians diagnose and evaluate medical conditions. These imaging scans use radioactive materials called radiopharmaceuticals or radiotracers.

Radiotracers are molecules linked to, or "labeled" with, a small amount of radioactive material that can be detected on the PET scan. They are designed to accumulate in cancerous tumors or regions of inflammation. They can also be made to bind to specific proteins in the body. The most commonly used radiotracer is F-18 fluorodeoxyglucose, or FDG, a molecule similar to glucose. Cancer cells may absorb glucose at a higher rate, being more metabolically active. This higher rate can be seen on PET scans, and that allows your doctor to identify disease before it may be seen on other imaging tests. FDG is just one of many radiotracers in use or in development for a variety of conditions throughout the body. Depending on the type of nuclear medicine exam, the radiotracer is either injected into the body, swallowed or inhaled as a gas and eventually accumulates in the organ or area of the body being examined. Radioactive emissions from the radiotracer are detected by a special camera or imaging device that produces pictures and provides molecular information. In many centers, nuclear medicine images can be superimposed with computed tomography (CT) or magnetic resonance imaging (MRI) to produce special views, a practice known as image fusion or coregistration. These views allow the information from two different exams to be correlated and interpreted on one image, leading to more precise information and accurate diagnoses. In addition, manufacturers are now making single photon emission computed tomography/computed tomography (SPECT/CT) and positron emission tomography/computed tomography (PET/CT) units that are able to perform both imaging exams at the same time. An emerging imaging technology, but not readily available at this time is PET/MRI.

Therapy: Nuclear medicine also offers therapeutic procedures, such as radioactive iodine (I-131) therapy that use small amounts of radioactive material to treat cancer and other medical conditions affecting the thyroid gland, as well as treatments for other cancers and medical conditions. Non-Hodgkin's lymphoma patients who do not respond to chemotherapy may undergo radioimmunotherapy (RIT). Radioimmunotherapy (RIT) is a personalized cancer treatment that combines radiation therapy with the targeting ability of immunotherapy, a treatment that mimics cellular activity in the body's immune system.

2.1.2 The common uses of the procedure:

Physicians use nuclear medicine imaging procedures to visualize the structure and function of an organ, tissue, bone or system within the body. In adults, nuclear medicine is used to:

Heart:

- Visualize heart blood flow and function (such as a myocardial perfusion scan).
- Detect coronary artery disease and the extent of coronary stenosis.
- Assess damage to the heart following a heart attack.
- Evaluate treatment options such as bypass heart surgery and angioplasty.

- Evaluate the results of revascularization (blood flow restoration) procedures detect heart transplant rejection.
- Evaluate heart function before and after chemotherapy (MUGA).

Lungs:

- Scan lungs for respiratory and blood flow problems.
- Assess differential lung function for lung reduction or transplant surgery
- Detect lung transplant rejection.

Bones:

- Evaluate bones for fractures, infection and arthritis.
- Evaluate for metastatic bone disease.
- Evaluate painful prosthetic joints.
- Evaluate bone tumors.
- Identify sites for biopsy.

Brain:

- Investigate abnormalities in the brain in patients with certain symptoms or disorders, such as seizures, memory loss and suspected abnormalities in blood flow.
- Detect the early onset of neurological disorders such as Alzheimer's disease.
- Assist in surgical planning and identify the areas of the brain that may be causing seizures.
- Evaluate for abnormalities in a chemical in the brain involved in controlling movement in patients with suspected Parkinson's disease or related movement disorders.
- Evaluation for suspected brain tumor recurrence, surgical or radiation planning or localization for biopsy.

Other Systems:

- Identify inflammation or abnormal function of the gallbladder.
- Identify bleeding into the bowel.
- Assess post-operative complications of gallbladder surgery.
- Evaluate lymphedema.
- Evaluate fever of unknown origin.
- Locate the presence of infection.
- Measure thyroid function to detect an overactive or underactive thyroid.
- Help diagnose hyperthyroidism and blood cell disorders.
- Evaluate for hyperparathyroidism (overactive parathyroid gland).
- Evaluate stomach emptying.
- Evaluate spinal fluid flow and potential spinal fluid leaks.

In adults and children, nuclear medicine is also used to:

Cancer:

- Stage cancer by determining the presence or spread of cancer in various parts of the body localize sentinel lymph nodes before surgery in patients with breast cancer or skin and soft tissue tumors
- Plan treatment.
- Evaluate response to therapy.
- Detect the recurrence of cancer.
- Detect rare tumors of the pancreas and adrenal glands.

Renal:

- Analyze native and transplant kidney blood flow and function.
- Detect urinary tract obstruction.
- Evaluate for hypertension (high blood pressure) related to the kidney arteries.
- Evaluate kidneys for infection versus scar.
- Detect and follow-up urinary reflux.

How should to be prepared?

Women should always inform their physician or technologist if there is any possibility that they are pregnant or if they are breastfeeding

You should inform your physician and the technologist performing your exam of any medications you are taking, including vitamins and herbal supplements. You should also inform them if you have any allergies and about recent illnesses or other medical conditions. Jewelry and other metallic accessories should be left at home if possible, or removed prior to the exam because they may interfere with the procedure. You will receive specific instructions based on the type of scan you are undergoing.

In some instances, certain medications or procedures may interfere with the examination ordered.

What does the equipment look like?

The special camera and imaging techniques used in nuclear medicine include the gamma camera and single-photon emission-computed tomography (SPECT). The gamma camera, also called a scintillation camera, detects radioactive energy that is emitted from the patient's body and converts it into an image. The gamma camera itself does not emit any radiation. The gamma camera is composed of radiation detectors, called gamma camera heads, which are encased in metal and plastic and most often shaped like a box, attached to a round circular donut shaped gantry. The patient lies on the examination table which slides in between two parallel gamma camera heads that are positioned above the patient and beneath the examination table. Sometimes, the gamma camera heads are oriented at a 90 degree angle and placed over the patient's body. SPECT involves the rotation of the gamma camera heads around the patient's body to produce more detailed, three-dimensional images. A PET scanner is a large machine with a round, donut shaped hole in the middle, similar to a CT or MRI unit. Within this machine are multiple rings of detectors that record the emission of energy from the radiotracer in your body. A computer aids in creating the images from the data obtained by the gamma camera. A probe is a small hand-held device resembling a microphone that can detect and measure the amount of the radiotracer in a small area of your body. There is no specialized equipment used during radioactive iodine therapy, but the technologist or other personnel administering the treatment may cover your clothing and use lead containers to shield the radioactive material you will be receiving.

How does the procedure work?

With ordinary x-ray examinations, an image is made by passing x-rays through the patient's body. In contrast, nuclear medicine procedures use a radioactive material, called a radiopharmaceutical or radiotracer, which is injected into the bloodstream, swallowed or inhaled as a gas. This radioactive material accumulates in the organ or area of your body being examined, where it gives off a small amount of energy in the form of gamma rays. Special cameras detect this energy, and with the help of a computer, create pictures offering details on both the structure and function of organs and tissues in your body. Unlike other imaging techniques, nuclear medicine imaging exams focus on depicting physiologic processes within the body, such as rates of metabolism or levels of various other chemical activity, instead of showing anatomy and structure. Areas of greater intensity, called "hot spots," indicate where large amounts of the radiotracer have accumulated and where there is a high level of chemical or metabolic activity. Less intense areas, or "cold spots," indicate a smaller concentration of radiotracer and less chemical activity.

In radioactive iodine (I-131) therapy for thyroid disease, radioactive iodine (I-131) is swallowed, absorbed into the bloodstream in the gastrointestinal (GI) tract and absorbed from the blood by the thyroid gland where it destroys cells within that organ. Radio immunotherapy (RIT) is a combination of radiation therapy and immunotherapy. In immunotherapy, a laboratory-produced molecule called a monoclonal antibody is engineered to recognize and bind to the surface of cancer cells. Monoclonal antibodies mimic the antibodies naturally produced by the body's immune system that attack invading foreign substances, such as bacteria and viruses. In RIT, a monoclonal antibody is paired with a radioactive material. When injected into the patient's bloodstream, the antibody travels to and binds to the cancer cells, allowing a high dose of radiation to be delivered directly to the tumor. In I-131MIBG therapy for neuroblastoma, the radiotracer is administered by injection into the blood stream. The radiotracer binds to the cancer cells allowing a high dose of radiation to be delivered to the tumor.

How is the procedure performed?

Nuclear medicine imaging is usually performed on an outpatient basis, but is often performed on hospitalized patients as well. You will be positioned on an examination table. If necessary, a nurse or technologist will insert an intravenous (IV) catheter into a vein in your hand or arm. Depending on the type of nuclear medicine exam you are undergoing, the dose of radiotracer is then injected intravenously, swallowed or inhaled as a gas. It can take anywhere from several seconds to several days for the radiotracer to travel through your body and accumulate in the organ or area being studied. As a result, imaging may be done immediately, a few hours later, or even several days after you have received the radioactive material. When it is time for the imaging to begin, the camera or scanner will take a series of images. The camera may rotate around you or it may stay in one position and you may be asked to change positions in between images. While the camera is taking pictures, you will need to remain still for brief periods of time. In some cases, the camera may move very close to your body. This is necessary to obtain the best quality images. If you are claustrophobic, you should inform the technologist before your exam begins. If a probe is used, this small hand-held device will be passed over the area of the body being studied to measure levels of radioactivity. Other nuclear medicine tests measure radioactivity levels in blood, urine or breath. The length of time for nuclear medicine procedures varies greatly, depending on the type of exam. Actual scanning time for nuclear imaging exams can take from 20 minutes to several hours and may be conducted over several days.

Young children may require gentle wrapping or sedation to help them hold still. If your doctor feels sedation is needed for your child, you will receive specific instructions regarding when and if you can feed your child on the day of the exam. A physician or nurse who specializes in pediatric anesthesia will be available during the exam to ensure your child's safety while under the effects of sedation. When scheduling the exam for a young child, ask if a child life specialist is available. A child life specialist is trained to make your child comfortable and less anxious without sedation and will help your child to remain still during the examination. When the examination is completed, you may be asked to wait until the technologist checks the images in case additional images are needed. Occasionally, more images are obtained for clarification or better visualization of certain areas or structures. The need for additional images does not necessarily mean there was a problem with the exam or that something abnormal was found, and should not be a cause of concern for you. If you had an intravenous line inserted for the procedure, it will usually be removed unless you are scheduled for an additional procedure that same day that requires an intravenous line. For patients with thyroid disease who undergo radioactive iodine (I-131) therapy, which is most often an outpatient procedure, the radioactive iodine is swallowed, either in capsule or liquid form. Radio immunotherapy (RIT), also typically an outpatient procedure, is delivered through injection. I-131MIBG therapy for neuroblastoma is administered by injection into the blood stream. Children are admitted to the hospital for treatment as an inpatient and will stay overnight in a specially prepared room. Special arrangements are made for parents to allow participation in the care of their child while undergoing this therapy.

What are the benefits vs. risks?

A- Benefits:

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. A nuclear medicine scan 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 benign or 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.

B- Risks

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.

2.1.3 The limitations of General Nuclear Medicine:

Nuclear medicine procedures can be time consuming. It can take several hours to days for the radiotracer to accumulate in the body part of interest and imaging may take up to several hours to perform, though in some cases, newer equipment is available that can substantially shorten the procedure time. The resolution of structures of the body with nuclear medicine may not be as high as with other imaging techniques, such as CT or MRI. However, nuclear medicine scans are more sensitive than other techniques for a variety of indications, and the functional information gained from nuclear medicine exams is often unobtainable by other imaging techniques.

2.2 Communication of radiation risk in nuclear medicine:

2.2.1 Estimation of radiation risk:

It is well-accepted that the estimation of radiation risk is not an exact science and most estimations are based on complex modeling derived from analysis of survivors of the Hiroshima and Nagasaki atomic disasters. This can be compared to the odds of winning a lottery ticket, but the persons hope to get lucky and beat the odds. Similarly, most patients undergoing nuclear medicine procedure would like to believe that the odds of developing some complications as a result of a diagnostic test are more theoretical than individually applicable. It is when this expectation of a purely theoretical risk is proved correct in the individual case or is proved to be a gross underestimate, the patients and their doctors go back to their discussions held prior to the test and whether those were “correct” or not.

2.2.2. Benefits of nuclear medicine tests:

The benefits of nuclear medicine procedure are relatively easier handle by the nuclear medicine professional. Indeed, more than 95% of articles published in peer reviewed journals are “biased” toward positive reporting, and very few journals accept and publish negative findings of diagnostic tests. However, most of these articles rely on comparison of tests rather than identifying true risks to patients. The ethical standard relies on ensuring a wide safety net to ensure that the research protocols are reasonably safe, and that the participants are informed. Very few standards exist that expect researchers to actually quantify the risks to individuals from participation in the research studies.

2.2.3 The risk versus benefit paradigm for radiation doses from investigations in nuclear medicine

While most decisions in medicine are made in the context of a detailed risk benefit analysis, the challenge is to communicate the risks and benefits of a particular procedure while adopting a neutral stance. It is for this reason that the risk to benefit analysis and the communication of this analysis is best performed by the referring physician and not by a nuclear medicine professional. When quizzed individually, let alone when challenged, most referring physicians will claim ignorance of the detailed risks of their patients undergoing nuclear medicine procedures. It is indeed up to the nuclear medicine professionals to educate their colleagues to an adequate level and for them to then communicate in an unbiased manner to patients.

2.2.4 Methods of communication of risk

Due to the complex nature of most nuclear medicine procedures, we rely on a combination of written and verbal information when we communicate risk. The language and tone of the information is crucial and this needs to be applicable in the local context and setting. The challenge is even more difficult when dealing with illiterate patients who may view doctors and other nuclear medicine professionals with immense respect and admiration, and hence feel that they cannot be challenged. The principle of consent to undergo a nuclear medicine procedure is based on a detailed understanding of the risks and benefits of the procedure in question.

2.2.5 Consent in nuclear medicine

While most nuclear medicine professionals seek written consent for therapeutic nuclear medicine procedures, majority departments do not need written consent for diagnostic procedures. In the past, it was possible that many physicians ignored issues with specifically consenting patients for investigations in nuclear medicine, as this was frequently considered an additional waste of time, resource and energy. Due to the strict legal interpretation of an "assault" on an individual in most countries, any no consented procedure such as a simple intravenous injection could be deemed as an assault on that individual. Consent could be given in writing or could be implied. It is generally accepted that if a patient attends a department and holds their arm out for an injection, there is implied consent to proceed. There should be clear local guidelines on what actually constitutes a consented procedure within the department. Documentation of consent, which may not necessarily be in a written format, is crucial and when challenged, the nuclear medicine professional should be able to clearly identify the steps involved in justification of the procedure and the consent itself. Doctors represent a caring profession and are deemed always to act in a patient's best interests, however, due to the realization that doctors are as much part of society as any other professional, there are professional standards that are expected and these can be monitored and quantified, should this be required. Doctors need to keep their knowledge updated, maintain professional attitudes at all times and they may need to change their practice as per each individual setting and indeed for each patient.

Doctors practicing nuclear medicine also need to adhere to the highest ethical standards in medicine.

2.2.6 Communication of benefit versus risk

The way to effective communication of risk lies in the knowledge that there is also a risk which arises when a condition is not diagnosed or treated because an investigation was not performed. For example, in a case of possible pulmonary embolism in a woman who is 28 weeks pregnant, there is a direct risk, which arises because of no diagnosis of this condition, if an investigation such as a lung perfusion-ventilation study is not carried out. The referring physician then has two options and of course he may be wrong in following either option because in the absence of an appropriate nuclear medicine investigation, he has no better way of knowing what option is actually correct. If he were to treat the patient with therapeutic anticoagulation and if the patient did not actually have a pulmonary embolism, then the patient runs the risk of bleeding during and after the pregnancy. This presents a risk to the life of the mother and fetus, which is not quantifiable but nevertheless such a risk, albeit small, does exist. If the referring physician takes the option not to treat the patient and if the patient did have a pulmonary embolus then this also presents a risk to the life of the mother and the fetus. The quantification of the risk is dependent in this case on the size and burden of the pulmonary embolus and on the presence or absence of impending right heart failure. Hence in this situation, there appears to be a definite benefit to the patient in undertaking the Nuclear Medicine investigation because here the benefits of the test far overweigh the risks involved, and the risks are not just "radiation" related risks, but also "clinical" risks.

2.2.7 How different communities handle risk

Every community handles communication of radiation risk differently. The active geopolitical and economic situation at the current time dictates the tone of communication, but the gist of the matter remains the same. For instance, in a wider context of political instability or natural disasters such as floods or earthquakes, it may not be appropriate to quote cancer risks as the long-term survival from the current situation cannot be taken for granted. The communication varies between "just a little information" or "no information at all" to perhaps even "information overload. It is the responsibility of the nuclear medicine professional to provide definitive guidance to the patient in a manner, which is easily understood and causes the least misunderstanding, prior to the procedure. There must also be an attempt to avoid technical jargon as the patient is unlikely to really understand what is being communicated. There is an opportunity to review the patient's own understanding of the risks involved and to update them accordingly if required.

2.2.8 Perception of risk from "anything nuclear" and the art of reassurance

It is important to understand when communicating the risk of radiation that unlike the physician, the patient may not gather information from accurate sources. Instead the patient may actually have his/her information from other sources which convey information varying from being only somewhat inaccurate in nature to being outright wrong. This problem arises partly because of patient factors such as patient background, education and age as well as the general misinformation about radiation, which may be perpetuated in popular and populist mass media.

Thus, some patients may have a wrong mental image of radiation, which may cause them quite a lot of anxiety. It depends on the long standing images and perception, which have been present in the mind of the patient. The seminal study by Slovic in 1987 showed that the general public may have fundamentally different ideas about risk arising from nuclear technology as opposed to experts in the field even when nuclear technology was compared to daily activities, which were quite risky in nature. While experts were of the opinion that activities arising from nuclear technology were quite safe, in the minds of quite a number of people from the lay population those very same activities were ranked number 1 in terms of risk. In these circumstances, it becomes incumbent on the Nuclear Medicine physician to reassure such patients.

2.2.9 The role of the Radiological Safety Officer/Radiation Protection Advisor

The Radiological Safety Officer or Radiation Protection Advisor is a technically qualified individual who can provide unbiased technical information on the measures that need to be taken to minimize radiation exposure to staff and patients. While this role could be performed by a clinically qualified individual, the primary role is one of reassurance to the hospital and to the public that all reasonable steps are being taken within the institution to reduce radiation exposure and hence reduce risk. In the most countries, this role has independent accountability and these individuals have to be involved in setting up protocols, assessment of equipment and also agreement on the level and type of patient information about radiation risk.

2.3 Ionizing radiation

The purpose of this section is to provide information on the basics of ionizing radiation for everyone. Energy emitted from a source is generally referred to as radiation. Examples include heat or light from the sun, microwaves from an oven, X rays from an X-ray tube, and gamma rays from radioactive elements.

Ionizing radiation is radiation with enough energy so that during an interaction with an atom, it can remove tightly bound electrons from the orbit of an atom, causing the atom to become charged or ionized.

Here we are concerned with only one type of radiation, ionizing radiation, which occurs in two forms - waves or particles. More information on Non-Ionizing radiation.

2.3.1 Forms of electromagnetic radiation.

These differ only in frequency and wave length.

- Heat waves.
- Radiowaves.
- Infrared light.
- Visible light.
- Ultraviolet light.
- X rays.
- Gamma rays

Longer wave length, lower frequency waves (heat and radio) have less energy than shorter wave length, higher frequency waves (X and gamma rays). Not all electromagnetic (EM) radiation is ionizing. Only the high frequency portion of the electromagnetic spectrum which includes X rays and gamma rays is ionizing.

2.3.2 Waves

Most of the more familiar types of electromagnetic radiation (e.g. visible light, radio waves) exhibit "wave-like" behavior in their interaction with matter (e.g. diffraction patterns, transmission and detection of radio signals). The best way to think of electromagnetic radiation is a wave packet called a photon. Photons are changeless bundles of energy that travel in a vacuum at the velocity of light, which is 300 000 km/sec.

2.3.3 Particulate

Specific forms of ionizing radiation: Particulate radiation, consisting of atomic or subatomic particles (electrons, protons, etc.) which carry energy in the form of kinetic energy or mass in motion.

Electromagnetic radiation, in which energy is carried by oscillating electrical and magnetic fields traveling through space at the speed of light.

Alpha particles and beta particles are considered directly ionizing because they carry a charge and can, therefore, interact directly with atomic electrons through coulombic forces (i.e. like charges repel each other; opposite charges attract each other).

The neutron is an indirectly ionizing particle. It is indirectly ionizing because it does not carry an electrical charge. Ionization is caused by charged particles, which are produced during collisions with atomic nuclei.

The third type of ionizing radiation includes gamma and X rays, which are electromagnetic, indirectly ionizing radiation. These are indirectly ionizing because they are electrically neutral (as are all electromagnetic radiations) and do not interact with atomic electrons through coulombic forces.

2.4.1Types ionizing radiation:

2.4.1.1 Alpha Decay:

Alpha particles (helium nuclei consisting of 2 protons and 2 neutrons) are radioactive decay products from radionuclides having large mass. Using standard nuclear notation, the parent element M with atomic number Z, and mass number A decay by alpha (α) emission as:

$^{A}_{Z}M$ = $^{A-4}_{Z-2}N$ + α + energy ……………………………………(2.1)

To the daughter product symbolized by N. Since alpha particles heve a + 2 charge and a large mass of 4 amu, they are very damaging to biologic systems and there- fore have no role in diagnostic nuclear medicine.

2.4.1.2 Beta decay:

The concept of a neutron being composed of a proton and electron is important in certain types of radioactive decay. A uncleus that is neutron rich becomes stable through the conversion of one of its neutrons by the reaction:

N = P + β- + ύ + energy ……………………………………(2.2)

As a result, a proton and an electron (β-) have been created from the neutron. The mass number of the new nuclei is the same as the parent nuclei, since the mass of neutron and proton are virtually the same, however different element remain. The β- particles that has been.

Created in the nucleus through this decay process is ejected. Neutrino and antineutrinos have no electrical charge and a mass of almost zero. They travel at the velocity of light and are almost undetectable. The excess energy from the neutron is shared between the beta particle and antineutrino (ύ). This sharing of kinetic energy is not equal. Sometimes the electron receives more of the energy and the neutrino receives less, or vice versa. As a result the energy of the beta particle varies in a continuous energy spectrum with some maximum energy (Emax) that was available form the nucleus. The nuclear decay process by this method is termed beta – minus (β-) or simply beta decay.The parent element M with atomic number Z and mass number A decay by beta emission as

$^{A}_{Z}M$ = $_{Z+1}^{A}N$ + β- + ύ + energy............................(2.3)

$A = \pi r^2$ The energy release by this process is shared as kinetic energy by the beta particle and the antineutrino. An example of beta – emitting radionuclide used in nuclear medicine is 1-131, which decay as follows:

$^{131}_{53}I$ = $^{131}_{54}Xe$ + β- + ύ ....(2.4)

2.4.1.3 Gamma Decay:

Gamma ray emission represents a mechanism for an exited nucleus to release energy. The release of energy as a gamma ray (γ) may be as a part of another decay process, such as alpha or β-. ln additional, it is the process for releasing energy from a metastable nucleus.

Gamma ray emission usually occurs when there is greater than 100 keV of energy in the excited nucleus. The ideal radionuclides for nuclear medicine are those that emit only gamma rays without emitting particulate radiation. These radionuclides therapy provide gamma rays for imaging without increasing patient radiation exposure.

The release from metastable state is termed an isomeric transition. ln this transition the nucleus goes from a high energy level to lower energy level through emission of electromagnetic radiation (usually greater than 100KeV); this is sometimes termed gamma decay The equation for an isomeric transition may be written follows:

$^{A}_{Z}M$ = $^{A}_{Z}M$ + γ..................... (2.5)

Metastable nuclei are the most pure sources of gamma rays for nuclear medicine imaging. ^{99m}Tc- has become the most important radionuclide in nuclear medicine imaging.

$^{99m}_{43}Tc = ^{99}_{43}Tc + \gamma$......................(2.6)

2.4.2 Interaction of Radiation with Matter:

2.4.2.1 Interaction of charge particles with matter:

Electrical charges (alpha particles, electrons, and positrons) have a high probability of interacting with the Matter through which they move. Their mass and electrical charges interact with the mass of nucleus and electrical charge of atoms. In addition, the kinetic energy of these particles, along with the properties of the surrounding matter, determines how the particles will interact and how far these particles will travel. The density of matter, its atomic number, and its mass number influence the type and probability of these interactions (Donald, 1997).

2.4.2.1.1 Beta particles:

The interaction of negatively beta particles in the proximity of the nucleus of an atom result in attraction to the positively charged nucleus. As the beta in particles is defalcated and showed in its path, there is a release of energy as X-rays, called bremsstrahlung radiation. Bremstrahlung interactions increase in probability with materials that have a high Z number.A beta particle emitting radionuclide should not be shielded with material of high atomic number Z. It is more appropriate to use a shielding material of low Z, such as plastic, since bremsstrahlung interactions are less likely to occur (O.ALI, 2001).

2.4.2.1.2 Electrons:

Positively and negatively charge electrons are antiparticles of one of on another When positrons are produce in a decay process and are and are ejected from an atom, they have enough kinetic energy to travel a maximum of a few millimeters.

The positron and an orbital electron from an atom are attracted due to their opposite charges, spiral in toward one another and interact in a process called annihilation. The mass of particles is converted into energy (0.511mev gamma rays) according to Einstein's equation $E = mc^2$. The detection of these gamma rays is the foundation for positron emission tomography (Robin Wilks).

2.4.2.2 Interaction of photons with matter:

Electromagnetic radiation is far more penetrating in matter than particulate type of radiation. For photons with energies associated with X-rays and gamma rays, three types of interactions occur. Photoelectric effect, Compton, and pair production.

2.4.2.2.1 photoelectric effect :

The photoelectric effect is an interaction that takes place between an incident photon and an inner orbital electron.the energy range is between several KeV to 0.5Mev. ln this interaction an ion pair has been formed with releasing of characteristic X rays (Donald, 1997).

2.42.2.2. Compton scattering:

Compton scattering is an incomplete absorption of gamma rays of scattering of gamma radiation. The Compton Effect involves an inelastic interaction of photon with outer orbital electrons. The range of the energy is between several KeV to several MeV.The secondary effect of this interaction is the production of Compton electron and scatter photon (Donald, 1997).

2.4.2.2.3 Pair production:

Pair production is an interaction produced when a photon with energy greater than 1.2Mev passe near the high electric field of nucleus.The secondary effect of this interaction is the production of positron, electrons, and annihilation photon (Donald, 1997).

2.4.3 The Biological Effect of Ionizing Radiation:

Radioactive substances can inter an organism in three ways, namely, with food and water into the gastrointestinal tract, through the lung and the skin.

The most important and potentially dangerous is the inhalation of radionuclides.

When any substance is irradiated by ionizing radiation, the radiant energy is transferred to the atoms and molecules of the substance, which will be excited and ionized, and this is the chemical stage of the radiation damage to cell.

The primary radiation chemical changes in nucleus can be produced by direct and in direct effect of radiation. The direct effect of radiation are meant changes such that appear as a result of the absorption of radiation energy by the molecules (target).The in direct effect of radiation are meant changes in the molecule in a solution caused by the products of radiation decomposition of water or other solutes, and not by the radiant energy absorbed by the molecules being studied.

The potential risks and biological consequences of nuclear medicine procedures are basically the same as for any other use of radiation, namely carcinogensis, genetic mutation, and on the developing embryo and fetus (Donald, 1997).

2.4.4 Radiation Protection Definition:

Protection and safety is defiend as (the protection of people against exposure to ionizing radiation or radioactive substance and the safety of radiation sources; including the means for achieving such protection and devices for keeping peoples doses and risks as low as prescribed dose constrains, as well as means for preventing accident and for mitigating the consequences of accidents shoud they occur) (Safty series, 1990).

The international Commission for Radiation Protection (ICRP), in it ICRP-60 made a recommendations for the doses to the workers and public. These recommendations were approved by the IAEA in Basic safety series BSS-155 and become the guide for the IAEA member state.

The regulation “Basic Requirements for Radiation Protection and Dose Limits” issued under Sudan Atomic Energy Commission (SAEC) Act, 1996, sets the Dose Limits for Workers and Publics as stated in BSS -115.

2.4.5 Radiation Dose Measurement and Units of Doses:

2.4.5.1 Exposure:

When abeam of X-ray radiation or gamma radiation passing through air it produces excitation and ionization of the air molecules. The electron ejected in the first interaction produces other secondary electrons by ionization, the net effect is formation of electric charges by ionization and absorption of energy by air when the electric charge are slowed down by collection. Exposure is a measure of total electric charge formed by ionization in unit mass of (Robin Wilks).

The exposure at particular point in a beam of gamma radiation is the ratio Q/m where Q is the total electric charge (of one sign) in a small volume of air of mass m (Dister, 1998s). The exposure only applies to the air and its unit is Roentgen.

2.4.5.2 Roentgen:

It was originally defined as the amount of X-ray or gamma radiation that produces one electrostatic unit of charge (esu) of either sign per cc of air at standard temperature and pressure.

It is defined currently in equivalent units as 2.58×10 coulomb /kg air. It turns out that this amount of radiation imports an amount of energy equal to 0. 87 rad to air.

A roentgen of X- ray in the energy range 0.1-3 Mev also produces 0.98 rad to tissue (KRU, 1962), thus for more purposes values of exposure in roentgen can be considered essentially numerically equal to absorption doses in rad to tissue irradiation at the same point or to does equivalent in rem(Jacob shapino).

2.4.5.3 Absorbed Dose:

Radiation damage often depends on the amount of energy absorbed per unit mass of the irradiated material. The quantity that specific the energy imported to a material by any type of ionizing radiation per unit mass at point of interest is termed absorbed dose. Absorbed dose (D) is defined as

$D=E/M$.....................(2.7)

Where the energy absorbed by material of mass m The SI unit for this quantity is the Gray.

2.4.5.4 Gray:

Defined as the energy deposition of 1 JouIe/kg of material. The concept of absorbed dose applies to all categories of ionizing radiation dosimeter to all materials, and to forms of ionizing radiation (Robin Wilks). The traditional unit is the rad, which is defined as energy deposition of 0.01 joule/kg. thus,

1gy =100 Rad…………......(2.8)

2.4.5.5 Equivalent dose:

The dose equivalent concept originated from the observation that different types of radiation can produce different biologic effect for the same absorbed dose (Jacob shapino).The dose equivalent is a computed types that expresses a measure of the biological harm imparted to tissue is defined by the flowing equation:

$H = W R$……………(2.9)

Where D is absorbed dose, WR is known as radiation weighting factor. The unit for (H) is the same as that of absorbed dose, but the special name for SI unit of dose equivalent is Sievert.

1 sievert (Sv) =1joule/kg……………(2.10)

If the dose is expressed in units of rad, the special unit for (H) is called rem.

1Sv = 100 rem…………………(2.11)

2.4.5.6 Effective Dose:

The effective Dose is the total sum of such weighted equivalent dose for all exposed tissues in an individual.

E = HW = DW.W……………(2.12)

Where W is called tissue –weighting factor, That some equivalent dose can produce different effects on different organs.

Radiation Detectors and Dosimetry:

There are many detectors by which a beam of X-ray or gamma ray can be detected. An estimation of the absorbed dose can made, each of which has its own particular advantages and disadvantageous. Some of these are out lined below.

2.4.5.7 Free Air Ionization Chamber:

In order to measure the exposure in an X-ray beam consistent with the definition the quantity, especial type of ionization chamber have been devised. Chamber designed to measure exposure in this way is called a free air ionization chamber.

The free air or standard ionization chamber is an instrument employed in the measurement of the exposure in roentgen according to its definition. Generally, such primary standard is used only for calibration of secondary installation are thus can find principally to some of the national laboratories.

The electrons produced by the photon beam in the specified volume must spend all their energy by ionization of the air between the plates. such condition can exist if the range of the electrons is less than the distance between each plate and the specified volume. In addition equilibrium to exist, the beam intensity must remain constant across the length of the specified volume, and separation between the diagram and the ions collecting region must exceed the electron range in the air.

2.5 Geiger counter

A Geiger counter is an instrument used for detecting and measuring ionizing radiation. Also known as a Geiger Mueller counter (or Geiger-Müller counter), it is widely used in applications such as radiation dosimetry, radiological protection, experimental physics, and the nuclear industry.

It detects ionizing radiation such as alpha particles, beta particles, and gamma rays using the ionization effect

The original detection principle was realized in 1908, at the Cavendish laboratory, but it was not until the development of the Geiger-Müller tube in 1928 that the Geiger counter could be produced as a practical instrument. Since then, it has been very popular due to its robust sensing element and relatively low cost. However, there are limitations in measuring high radiation rates and the energy of incident radiation.

2.5.1 Principle of operation

Schematic of a Geiger counter using an "end window" tube for low penetration radiation. A loudspeaker is also used for indication

Müller tube (the sensing element which detects the radiation) and the processing electronics, which displays the result.

The Geiger-Müller tube is filled with an inert gas such as helium, neon, or argon at low pressure, to which a high voltage is applied. The tube briefly conducts electrical charge when a particle or photon of incident radiation makes the gas conductive by ionization. The ionization is considerably amplified within the tube by the Townsend discharge effect to produce an easily measured detection pulse, which is fed to the processing and display electronics. This large pulse from the tube makes the Geiger counter relatively cheap to manufacture, as the subsequent electronics are greatly simplified. The electronics also generate the high voltage, typically 400–900 volts that has to be applied to the Geiger-Müller tube to enable its operation. To stop the discharge in the Geiger-Müller tube a little halogen gas or organic material (alcohol) is added to the gas mixture.

2.5.2 Readout

There are two types of detected radiation readout: counts or radiation dose. The counts display is the simplest and is the number of ionizing events detected displayed either as a count rate, such as "counts per minute" or "counts per second", or as a total number of counts over a set time period (an integrated total). The counts readout is normally used when alpha or beta particles are being detected. More complex to achieve is a display of radiation dose rate, displayed in a unit such as the sievert which is normally used for measuring gamma or X-ray dose rates. A Geiger-Müller tube can detect the presence of radiation, but not its energy, which influences the radiation's ionizing effect. Consequently, instruments measuring dose rate require the use of an energy compensated Geiger-Müller tube, so that the dose displayed relates to the counts detected. The electronics will apply known factors to make this conversion, which is specific to each instrument and is determined by design and calibration.

The readout can be analog or digital, and modern instruments are offering serial communications with a host computer or network.

There is usually an option to produce audible clicks representing the number of ionization events detected. This is the distinctive sound normally associated with hand held or portable Geiger counters. The purpose of this is to allow the user to concentrate on manipulation of the instrument whilst retaining auditory feedback on the radiation rate.

2.5.3 Limitations

There are two main limitations of the Geiger counter. Because the output pulse from a Geiger-Müller tube is always of the same magnitude (regardless of the energy of the incident radiation), the tube cannot differentiate between radiation types. Secondly, the inability to measure high radiation rates due to the "dead time" of the tube. This is an insensitive period after each ionization of the gas during which any further incident radiation will not result in a count, and the indicated rate is, therefore, lower than actual. Typically the dead time will reduce indicated count rates above about 104 to 105 counts per second depending on the characteristic of the tube being used. While some counters have circuitry which can compensate for this, for accurate measurements ion chamber instruments are preferred for high radiation rates.

2.6 Previous Studies:

Ashish, Kumar, and et al reported estimation of radiation dose received by the radiation worker during F-18 FDG injection process, included the effective whole body doses to the radiation workers involved in injections of 1511 patients over a period of 10 weeks were evaluated using pocket dosimeter. Each patient was injected with 5MBq/kg of F-18 FDG injection protocol followed in our department is as follows. The technologist dispenses the dose to be injected and records the per-injection activity. The nursing staff members then secure an intravenous catheter. The nuclear medicine physicians/residents inject the dose on a rotation basis in accordance with ALARA principle

After the injection of the tracer, the nursing staff members flushed the intravenous catheter. The person who injected the tracer then measured the post-injection residual dose in the syringe.

From the results of this study the mean effective whole body doses per injection for the staff were the following:Nurses received 1.44 ± 0.22 μsv/injection (3.71 ± 0.48 nsv/MBq), for doctors the dose values were

2.44 ± 0.25μsv/injection (6.29±0.49 nsv/MBq) and for techologists the doses were 0.61±0.10 μsv/injection (1.58±0.21 nsv/MBq).It was seen that the mean effective whole body per injection of our positron emission tomography/computed tomography (PET/CT) staff who were involved in the F-18 FDG injection process was maximum for doctors (54.34% differential doses), followed by nurses(32.02% differential doses) and technologist(13.64% differential doses).

This study confirms that low levels of radiation dose are received by staff during F18-FDG injection and these values can be used as a reference to allay any anxiety in the radiation workers.

Reported of radiation dose to technologists per nuclear medicine examination and estimation of annual dose. This study used a Geiger-muller detector to measure dose rates to technologists at various distances from patients at various distances from patients (0.25, 0.50, 1, and 2 m and behind a lead shield) and determined the average time spent by technologists at these distances. Deep-dose equivalents to technologists were obtained. The following conventional nuclear medicine procedures were considered: thyroid scintigraphy performed using 99mTc pertechnetate, whole –body bone scanning performed using 99mTc methylene diphosphonate, myocardial perfusion scanning performed using 99mTc methoxyisobutyl isonitrile, and 201TI (thallous chloride) and renal scanning performed using 99mTc –dimercaptosuccining acid.

The results of this study the measured deep-dose equivalent to technologists per procedure was within the range of 0.13± 0.05 to 0.43±0.17μsv using alead shield and 0.12± 0.07 to 1.01± 0.46μsv without a lead shield.Also, the annual individual dose to a technologist performing only a particular scintigraphic procedure throughout a year was estimated.

For a total of 95 clinical cases (71 patients), effective external radiation doses to technologists were found to be within the permissible levels.This study showed that a 2-mm lead shield markedly reduced the external dose to technologists. The doses to technologists varied significantly for different diagnostic applications. Consequently performing only a particular scintigraphic procedure is very different from one type of procedure to another. The results of this study should help in determining the rotation time of technologists in different procedures and different in their individual techniques.

Misbah Javed, Saeed Ur Rahman, and et al reported of measurement of radiation doses to occupational workers in nuclear medicine.

Were the atotal 80 patient were randomly seiected the study. These were injected with either 99mTc pertechnetate or 99Tc (methylene diphosphonate).The dose rate was measured in hot lab, waiting room and in the scanning room at distances of 10, 50 and 100 cm from the patient at different time intervals by using a radiation survey meter. The absorbed dose from radioactive patient to radiation workers was calculated by using RADARsoftware and mathematical formulae from the measured dose rate.

Were the results of this study the mean dose rate from thyroid scan atients at distance of 10, 50 and 100 cm, after administration of injection was found to be 41µsv/h, 31µsvlh and 22µsv /h respectively, whereas the dose rate from bone scan patients was calculated at 62µsv/h, 31µsv/h and 28µsv/h. The dose rate was also measured after 15 min and 30 min in waiting and scanning room for the same patient. The mean absorbed dose to nuclear medicine occupational workers calculated both manually and using RADAR software came out to be less than 1msv/year.

The external doses to radiation worker were within permissible level The results obtained in the present study are comparable to the previous studies conducted worldwide. The radiation dose level to occupational worker in our nuclear medicine department does not exceed the recommended dose limits for workers.

Chapter Three

Materials and Methods

3.1 Materials:

3.1.1 Survey Meter:

Survey meter in radiation protection are hand-held ionizing radiation measurement instrument used to check such as personnel, equipment and the environment for radioactive contamination and ambient radiation. The hand-held survey meter is probably the most familiar radiation measuring device owing to its wide and visible use.

3.1.2 Types of Survey Meter:

The most commonly used hand-held survey meter are the scintillation counter, which is used in the measurement of alpha, beta and neutron particles, the Geiger counter widely used for the measurement of alpha, beta and gamma levels and the ion chamber which is used for beta, gamma and x-ray measurement.

3.2 Methods:

Survey meter Reading:

3.2.1 Location:

The measurement were carried out using survey meter, survey meter were put in places:

1. Hot lab.
2. Injection.
3. Imaging room.
4. Waiting room.

In every location the survey meter was used to monitor the environmental radiation. The measurement is done during the period from 14/5/2018 to 14/7/2018 at times 12:00 pm.

3.2.2 Survey Meter Calibration:

The RDS-120 used in this work calibrated by the Secondary Standard Dosimeter Laboratory “SSDL” of SAEC. The calibration factor 1.

3.3 Statistical Methods: the use of comparative analytical method using the SPSS (Statistical Package for Social Science) program based on descriptive statistics and comparative and association hypothesis tests (0.05 sig. level), to demonstrate the differences in Al-Nilain Medical center and Royal Care Hospital, regarding the studies of active doses in (Bones) and (Thyroid).

t-test and F test were used to study the hypothesis which states that there were no significant differences in the doses mean of (Al-Nilain Medical center and Royal Care Hospital, regarding the studies of active doses in (Bones) and (Thyroid), respectively in hospitals and rooms.

Chapter Four

Results

Table 4.1: Activity dose in bones and thyroid for Al-Nilain Medical center:

	ROOM	Activity dose in case bones/20mCI (µsv/h)	Activity dose in case thyroid/5mCI (µsv/h)
DAY (1)	hot lab	0.002631	0.004385
	Injection	0.000526	0.000263
	Waiting	0.000351	0.001754
	Iamging	0.002631	0.003508
DAY (2)	hot lab	0.001754	0.004385
	Injection	0.000175	0.000175
	Waiting	0.000175	0.000877
	Iamging	0.000877	0.002631
DAY (3)	hot lab	0.004385	0.003508
	Injection	0.000263	0.000263
	Waiting	0.000175	0.001754
	Iamging	0.004385	0.002631
DAY (4)	hot lab	0.003508	0.003508
	Injection	0.000614	0.001754
	Waiting	0.000439	0.001754
	Iamging	0.004385	0.002631
DAY (5)	hot lab	0.001754	0.002631
	Injection	0.000263	0.000877
	Waiting	0.000087	0.000877
	Iamging	0.003508	0.002631

Table 4.2: Activity dose in bones and thyroid for Royal Care Hospital:

	ROOM	Activity dose in case bones/20mCI (µsv/h)	Activity dose in case thyroid/5mCI (µsv/h)
DAY (1)	hot lab	0.004385	0.002631
	Injection	0.000526	0.000175
	Waiting	0.000263	0.000175
	Iamging	0.002631	0.001754
DAY (2)	hot lab	0.004385	0.003508
	Injection	0.000439	0.000614
	Waiting	0.000263	0.000439
	Iamging	0.001754	0.002631
DAY (3)	hot lab	0.002631	0.003508
	Injection	0.002631	0.000175
	Waiting	0.000877	0.000263
	Iamging	0.003508	0.002631
DAY (4)	hot lab	0.004385	0.002631
	Injection	0.001754	0.000526
	Waiting	0.000877	0.000351
	Iamging	0.004385	0.002631
DAY (5)	hot lab	0.002631	0.002631
	Injection	0.001754	0.000877
	Waiting	0.001754	0.001754
	Iamging	0.003508	0.003508

Table 4.3: Distribution of mean active dose with respect to hospital:

	Active dose	
Hospital	Bones	Thyroid
Al-Nilain Medical Center	0.0016±0.0016	0.0021±0.0013
Royal Care hospital	0.0023±0.0015	0.0017±0.0013

Table (4.3) shows that the mean active doses in Al-Nilain Medical Center were (0.0016±0.0016Msv/h and 0.0021±0.0013Msv/h), respectively for bones and thyroid, while in Royal Care hospital were (0.0023±0.0015Msv/h and 0.0017±0.0013Msv/h), respectively for bones and thyroid.

Table 4.4: Distribution of mean active dose with respect to survey time:

	Active dose	
Time	Bones	Thyroid
Day1	0.0022±0.0020	0.0019±0.0015
Day2	0.0017±0.0016	0.0015±0.0012
Day3	0.0016±0.0016	0.0019±0.0012
Day4	0.0021±0.0013	0.0021±0.0012
Day5	0.0022±0.0016	0.0021±0.0017

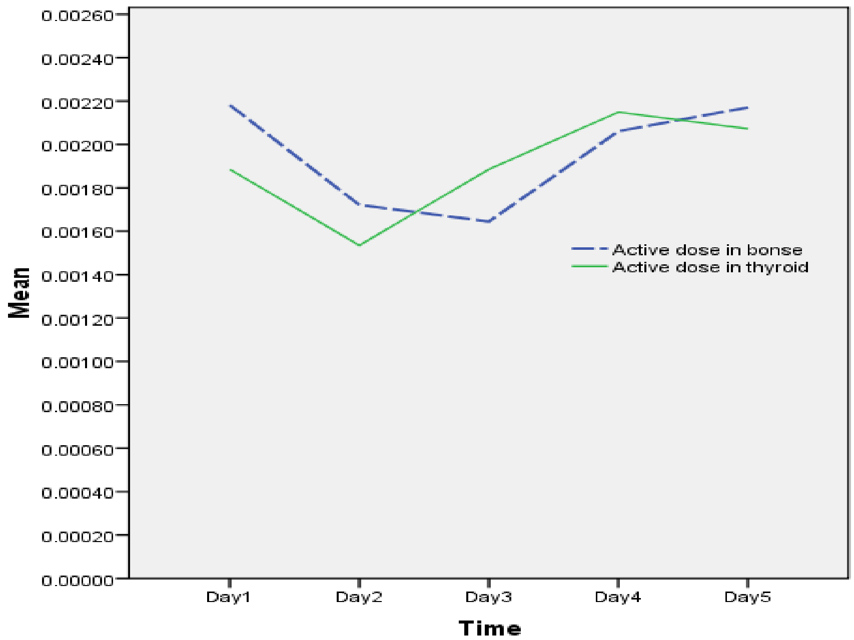

Figure 4.1: Distribution of mean active dose with respect to survey time

Table (4.4) and figure (4.1) show that the mean active doses for bones and thyroid respectively, were (0.0022±0.0020Msv/h and 0.0019±0.0015Msv/h) in first day, since they were (0.0017±0.0016Msv/h and 0.0015±0.0012Msv/h) in second day, (0.0016±0.0016Msv/h and 0.0019±0.0012Msv/h) in third day, (0.0021±0.0013Msv/h and 0.0021±0.0012Msv/h) in forth, while they were (0.0022±0.0016Msv/h and 0.0021±0.0017Msv/h) in the last day of survey.

Table 4.5: Distribution of mean active dose with respect to room:

Room	**Active dose**	
	Bones	Thyroid
Hot lab	0.0032±0.0011	0.0033±0.0007
Injection room	0.0009±0.0008	0.0006±0.0005
Waiting room	0.0005±0.0005	0.0010±0.0007
Imaging room	0.0032±0.0012	0.0027±0.0005

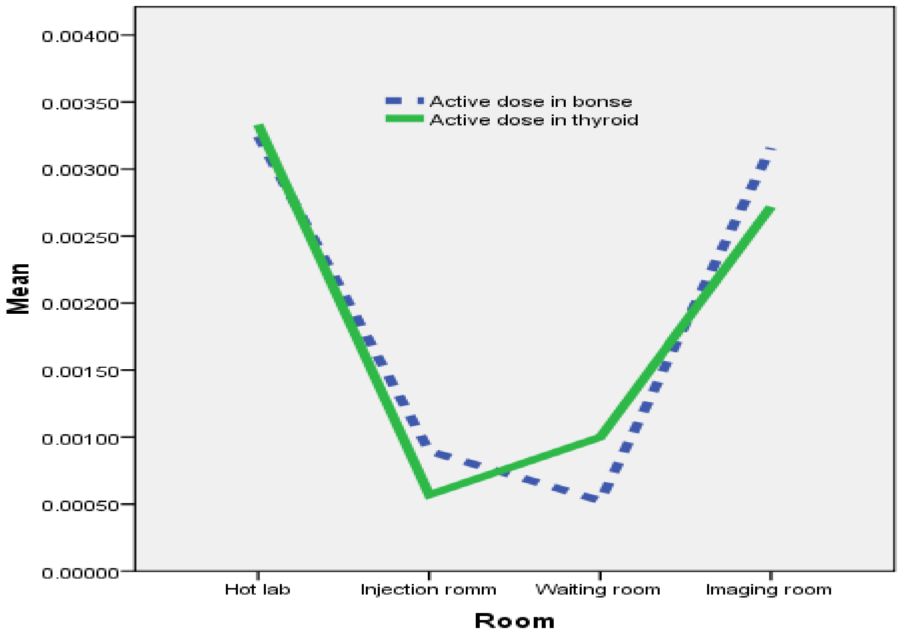

Figure 4.2: Distribution of mean active dose with respect to room

Table (4.5) and figure (4.2) show that the mean active doses for bones and thyroid respectively, were (0.0032±0.0011Msv/h and 0.0033±0.0007Msv/h) in hot lab, since they were (0.0009±0.0008Msv/h and 0.0006±0.0005Msv/h) in injection room, and (0.0005±0.0005Msv/h and 0.0010±0.0007Msv/h) in waiting room, while they were (0.0032±0.0012Msv/h and 0.0027±0.0005Msv/h) in imaging room.

Chapter Five

Dissuasion, Conclusion and Recommendations

5.1 Discussion:

Tables (4.3) and (4.4) provide the descriptive statistics for the two hospitals that we compared, including the mean of activity dose in bones and thyroid.

Figure (4.2) shows that the mean active doses for bones and thyroid in which the radiation dose in hot lab and imaging room is more than in injection room and waiting room

The Amount of radiation was notes to be very high for bones 20mci and thyroid 5mci scan doses at the hot lab and imaging room, As compared to the other rooms in the two centers.

The cause of this high radiation was that hot lab is the place of all radiation does result from doses preparation and generation elution .As for the imaging room the high radiation was due to radiation coming from the patient.

5.2 Conclusion:

This study was conducted in the nuclear departments at Al-nilian and Royal care hospitals during the period from July and September 2018.The main objective of the study was to evaluate the radiation dose in Al-nilain and Royal care hospitals nuclear departments.

The instrument used was a survey meter to measure the level of radiation in the (hot lab room, waiting room, injection room, and imaging room) for bones and thyroid scan respectively. That is because the bone scan usually takes the higher radiation dose, and the thyroid takes the lower dose for imaging process.

The study has come out with many results the most important of which was that the level of radiation was higher in the imaging room and the preparation room in the two centers under study.

However, there were minor differences between two centers in all aspects.

The study proposes some recommendations which could be useful in the study.

5.3 Recommendations:

-There should be more than one nuclear medicine technologists in the nuclear medicine department, so that they can routinely change each other to decrease the radiation doses.

-Routine survey to the nuclear medicine department rooms, especially the hot lab should be done.

-To decrease the staff exposure and contamination, a decontamination kit should always be kept fully stocked and handy to the work area. The kit should contain all the necessary tools and facilities.

-The personal radiation monitoring devices should be available in any nuclear medicine department in Sudan.

- Future studies in this field should include more departments and modern measurement tools.

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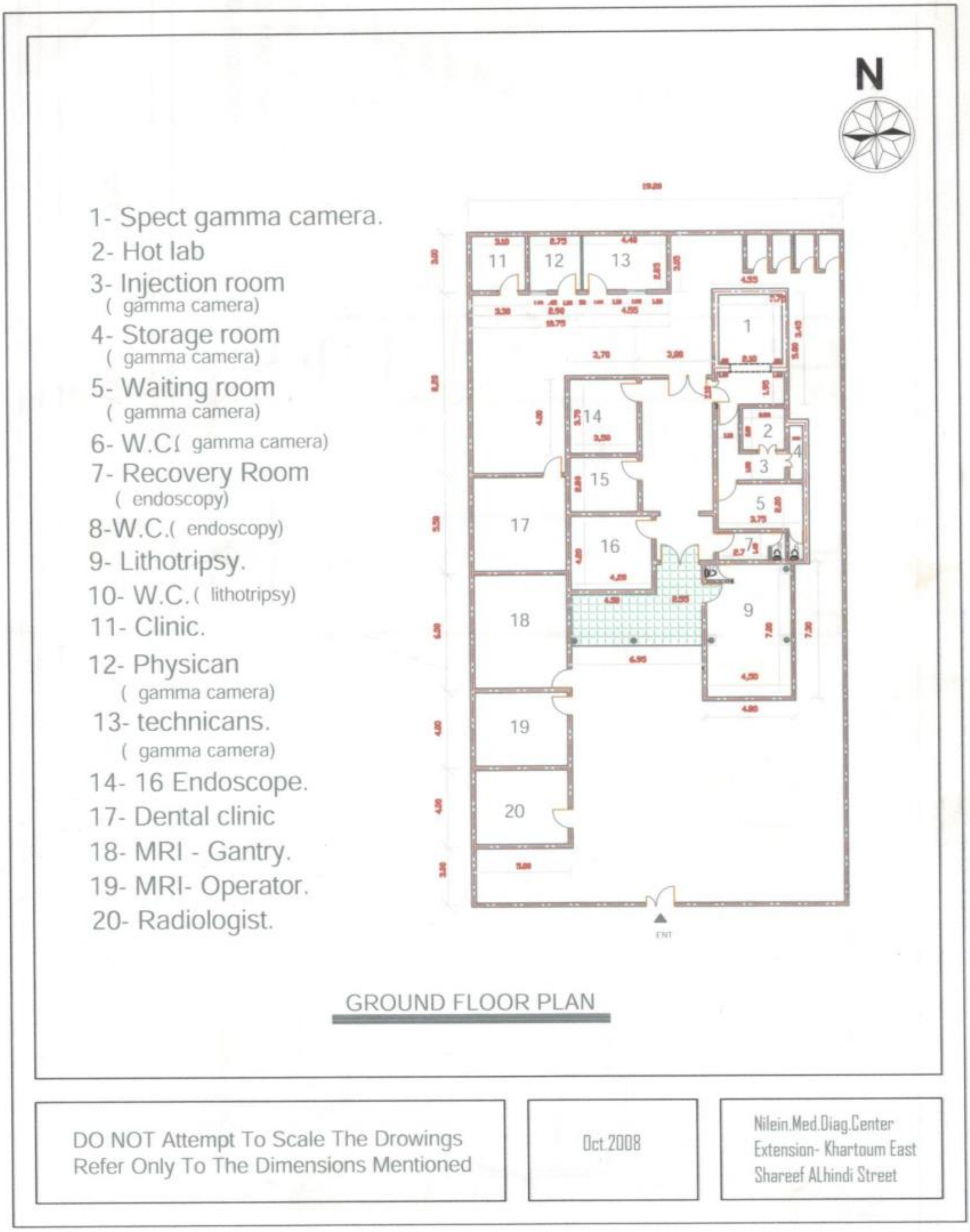
Appendices

Appendix 1: Study location



Appendix 2: survey meter