Introduction

1.1 Historical review of nuclear medicine:

Nuclear medicine is a medical specialty involving the application of radioactive substances in the diagnosis and treatment of disease. In nuclear medicine procedures, radionuclide's are combined with other elements to form chemical compounds, or else combined with existing pharmaceutical compounds, to form radiopharmaceuticals. These radiopharmaceuticals, once administered to the patient, can localize to specific organs or

cellular receptors. This property of radiopharmaceuticals allows nuclear medicine the ability to image the extent of a disease-process in the body, based on the cellular function and physiology, rather than relying on physical changes in the tissue anatomy. In some diseases nuclear medicine studies can identify medical problems at an earlier stage than other diagnostic tests. Nuclear medicine, in a sense, is "radiology done inside out" or "endo-radiology" because it records radiation emitting from within the body rather than radiation that is generated by external sources like X-rays. Treatment of diseased tissue, based on metabolism or uptake or binding of a particular ligand, may also be accomplished, similar to other areas of pharmacology. However, the treatment effects of radiopharmaceuticals rely on the tissue-destructive power of short-range ionizing radiation.

In the future, nuclear medicine may provide added impetus to the field known as molecular medicine. As understanding of biological processes in the cells of living organism expands, specific probes can be developed to allow visualization, characterization, and quantification of biologic processes at the cellular and subcellular levels. Nuclear medicine is a possible specialty for adapting to the new discipline of molecular medicine, because of its emphasis on function and its utilization of imaging agents that are specific for a particular disease process. The history of nuclear medicine is rich with contributions from gifted scientists across different disciplines in physics, chemistry, engineering, and medicine. The multidisciplinary nature of nuclear medicine makes it difficult for

medical historians to determine the birthdate of nuclear medicine. This can probably be best placed between the discovery of artificial radioactivity in 1934 and the production of radio nuclides by Oak Ridge National Laboratory for medicine related use, in 1946. The origins of this medical idea date back as far as the mid-1920s in Freiburg, Germany, when George de Hevesy made experiments with radionuclides administered to rats, thus displaying metabolic pathways of these substances and establishing the tracer principle. Possibly, the genesis of this medical field took place in 1936, when John Lawrence, known as "the father of nuclear medicine", took a leave of absence from his faculty position at Yale Medical School, to visit his brother Ernest Lawrence at his new radiation laboratory (now known as the Lawrence Berkeley National Laboratory) in Berkeley, California. Later on, John Lawrence made the first application in patients of an artificial radionuclide when he used phosphorus-32 to treat leukemia.

Many historians consider the discovery of artificially produced radionuclides by Frédéric Joliot-Curie and Irène Joliot-Curie in 1934 as the most significant milestone in nuclear medicine. In February 1934, they reported the first artificial production of radioactive material in the journal

Nature, after discovering radioactivity in aluminum foil that was irradiated with a polonium preparation . Their work built upon earlier discoveries by Wilhelm Konrad Roentgen for X-ray, Henri Becquerel for radioactive uranium salts, and Marie Curie (mother

of Irene Curie) for radioactive thorium, polonium and coining the term "radioactivity." Taro Takemi studied the application of nuclear physics to medicine in the 1930s. The history of nuclear medicine will not be complete without mentioning these early pioneers.

Nuclear medicine gained public recognition as a potential specialty on December 7, 1946 when an article was published in the Journal of the American Medical Association by Sam Seidlin. The article described a successful treatment of a patient with thyroid cancer metastases using radioiodine (I-131). This is considered by many historians as the most important article ever published in nuclear medicine. Although, the earliest use of I-131 was devoted to therapy of thyroid cancer, its use was later expanded to include imaging of the thyroid gland, quantification of the thyroid function, and therapy for hyperthyroidism. Widespread clinical use of nuclear medicine began in the early 1950s, as knowledge expanded about radionuclides, detection of radioactivity, and using certain radionuclides to trace biochemical processes. Pioneering works by Benedict Cassen in developing the first rectilinear scanner and Hal O. Anger's scintillation camera (Anger camera) broadened the young discipline of nuclear medicine into a full-fledged medical imaging specialty.

In these years of nuclear medicine, the growth was phenomenal. The Society of Nuclear Medicine was formed in 1954 in Spokane, Washington, USA. In 1960, the Society began publication of the Journal of Nuclear Medicine, the premier scientific journal for the discipline in America. There was a flurry of research and

development of new radionuclides and radiopharmaceuticals for use with the imaging devices and for in-vitro studies5. Among many radionuclides that were discovered for medical-use, none were as important as the discovery and development of Technetium-99m. It was first discovered in 1937 by C. Perrier and E. Segre as an artificial element to fill space number 43 in the Periodic Table. The development of a generator system to produce Technetium-99m in the 1960s became a practical method for medical use. Today, Technetium-99m is the most utilized element in nuclear medicine and is employed in a wide variety of nuclear medicine imaging studies.

By the 1970s most organs of the body could be visualized using nuclear medicine procedures. In 1971, American Medical Association officially recognized nuclear medicine as a medical specialty.[8] In 1972, the American Board of Nuclear Medicine was established, cementing nuclear medicine as a stand-alone medical specialty. In the 1980s, radiopharmaceuticals were designed for use in diagnosis of heart disease. The development of single photon emission computed tomography (SPECT), around the same time, led to three-dimensional reconstruction of the heart and establishment of the field of nuclear cardiology.

More recent developments in nuclear medicine include the invention of the first positron emission tomography scanner (PET). The concept of emission and transmission tomography, later developed into single photon emission computed tomography (SPECT), was introduced by

David E. Kuhl and Roy Edwards in the late 1950s.Their work led to the design and construction of several tomographic instruments at the University of Pennsylvania. Tomographic imaging techniques were further developed at the Washington University School of Medicine. These innovations led to fusion imaging with SPECT and CT by Bruce Hasegawa from University of California San Francisco (UCSF), and the first PET/CT prototype by D. W. Townsend from University of Pittsburgh in 1998

PET and PET/CT imaging experienced slower growth in its early years owing to the cost of the modality and the requirement for an on-site or nearby cyclotron. However, an administrative decision to approve medical reimbursement of limited PET and PET/CT applications in oncology has led to phenomenal growth and widespread acceptance over the last few years, which also was facilitated by establishing 18F-labelled tracers for standard procedures, allowing work at non-cyclotron-equipped sites. PET/CT imaging is now an integral part of oncology for diagnosis, staging and treatment monitoring. A fully integrated MRI/PET scanner is on the market from early 2011.

1.2 Radiation dose and risks in nuclear medicine:

A patient undergoing a nuclear medicine procedure will receive a radiation dose. Under present international guidelines it is assumed that any radiation dose, however small, presents a risk. The radiation doses delivered to a patient in a nuclear medicine investigation, though unproven, is generally accepted to present

a very small risk of inducing cancer. In this respect it is similar to the risk from X-ray investigations except that the dose is delivered internally rather than from an external source such as an X-ray machine, and dosage amounts are typically significantly higher than those of X-rays. The radiation dose from a nuclear medicine investigation is expressed as an effective dose with units of Sieverts (usually given in millisieverts, mSv). The effective dose resulting from an investigation is influenced by the amount of radioactivity administered in mega Becquerel's (MBq), the physical properties of the radiopharmaceutical used, its distribution in the body and its rate of clearance from the body.

Effective doses can range from 6 µSv (0.006 mSv) for a 3 MBq chromium-51 EDTA measurement of glomerular filtration rate to 37 mSv (37,000 µSv) for a 150 MBq thallium-201 non-specific tumor imaging procedure. The common bone scan with 600 MBq of technetium-99m-MDP has an effective dose of approximately 3.5 mSv (3,500 µSv) (1).

Formerly, units of measurement were the curie (Ci), being 3.7E10 Bq, and also 1.0 grams of Radium (Ra-226); the rad (radiation absorbed dose), now replaced by the gray; and the rem (Röntgen equivalent man), now replaced with the sievert. The rad and rem are essentially equivalent for almost all nuclear medicine procedures, and only alpha radiation will produce a higher Rem or Sv value, due to its much higher Relative Biological Effectiveness (RBE). Alpha emitters are nowadays rarely used in nuclear medicine, but were used extensively before the advent of nuclear

reactor and accelerator produced radionuclides. The concepts involved in radiation exposure to humans are covered by the field of Health Physics. The radioactive tracer used during nuclear heart scanning exposes the body to a very small amount of radiation. No long-term effects have been reported from these doses.

Radiation dose might be a concern for people who need multiple scans. However, advances in hardware and software may greatly reduce the radiation dose people receive. Some people are allergic to the radioactive tracer, but this is rare. If you have coronary heart disease, you may have chest pain during the stress test while you're exercising or taking medicine to raise your heart rate. Medicine can relieve this symptom. If you're pregnant, tell your doctor or technician before the scan. It might be postponed until after the pregnancy.

1.3 Problem of study:

The nuclear medicine is very important in the diagnosis and hence treatment of various diseases, as well as in the formulation of the treatment plan for the patient, and the examinations characterized as easily and there is no damage to the body, But the radioactive material injected in the patient for heart examination had potential hazard to the patient and the working staff required investigation for conformation of radiation hazard.

1.4 Objectives:

The general objective of this study was to Measure the patient dose in heart scintgraphy examination to evaluate the risk of radiation

Specific objective:

- To Measure of patient dose in heart scans
- To Estimate organ dose and radiation risk
- To find association between effective dose and body characteristic(weight,height,age,and BMI)

1.5 Importance of study:

Estimate the radiation dose that is given to the patient and reduce the radiation hazard in the diagnosis of heart disease using Technetium-99m in the presence of a gamma camera and access the correct results.

1.6 Thesis outlines:

This thesis is concerned with assessment of Measurement of patient dose in heart scan and Estimation of organ dose and radiation risk, it is divided into the following chapters:

Chapter one contains the introduction and discusses the problem, important of study and objectives.

Chapter two contains the theoretical background and also includes a previous study in this work and methods of dose estimation in nuclear medicine.

Chapter three describes the materials and the methods

Chapter four presents the results of this study.

Chapter five represents the discussion, conclusion and recommendations.

Theoretical background

2.1 Gamma Camera:

A gamma camera, also called a scintillation camera or Anger camera, is a device used to image gamma radiation emitting radioisotopes, a technique known as scintigraphy. The applications of scintigraphy include early drug development and nuclear medical imaging to view and analyze images of the human body or the distribution of medically injected, inhaled, or ingested radionuclide's emitting gamma rays.

2.1.1 Construction:

Figure 2.1: Gamma camera

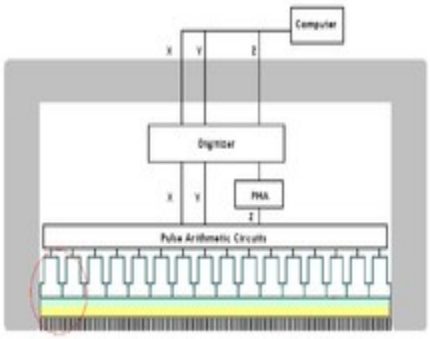

Figure 2.2: Diagrammatic cross section of a gamma camera detector

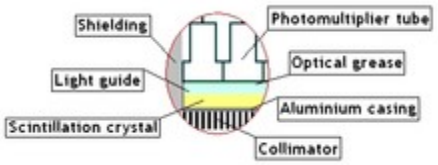

Figure 2.3: details of the cross section of a gamma camera

A gamma camera consists of one or more flat crystal planes (or detectors) optically coupled to an array of photomultiplier tubes, the assembly is known as a "head", mounted on a gantry. The gantry is connected to a computer system that both controls the operation of the camera as well as acquisition and storage of acquired images.

The system accumulates events, or counts, of gamma photons that are absorbed by the crystal in the camera. Usually a large flat crystal of sodium iodide with thallium doping in a light-sealed housing is used. The highly efficient capture method of this combination for detecting gamma rays was discovered by noted physicist Robert Hofstadter in 1948).

The crystal scintillates in response to incident gamma radiation. When a gamma photon leaves the patient (who has been injected with a radioactive pharmaceutical), it knocks an electron loose from an iodine atom in the crystal, and a faint flash of light is produced when the dislocated electron again finds a minimal energy state. The initial phenomenon of the excited electron is similar to the photoelectric effect and (particularly with gamma rays) the Compton effect. After

the flash of light is produced, it is detected. Photomultiplier tubes (PMTs) behind the crystal detect the fluorescent flashes (events) and a computer sums the counts. The computer reconstructs and displays a two dimensional image of the relative spatial count density on a monitor. This reconstructed image reflects the distribution and relative concentration of radioactive tracer elements present in the organs and tissues imaged.

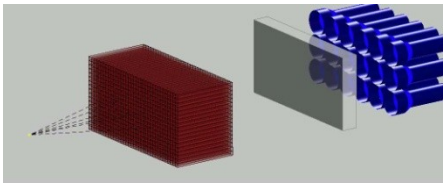

Figure 2.4: Animated schematic of gamma-camera physics and main constituents

2.1.2 Signal processing:

Hal Anger developed the first gamma camera in 1957. His original design, frequently called the Anger camera, is still widely used today. The Anger camera uses sets of vacuum tube photomultipliers (PMT). Generally each tube has an exposed face of about 7.6 cm in diameter and the tubes are arranged in hexagon configurations, behind the absorbing crystal. The electronic circuit connecting the photodetectors is wired so as to reflect the relative coincidence of light fluorescence as sensed by the members of the hexagon detector array. All the PMTs

simultaneously detect the (presumed) same flash of light to varying degrees, depending on their position from the actual individual event. Thus the spatial location of each single flash of fluorescence is reflected as a pattern of voltages within the interconnecting circuit array.

The location of the interaction between the gamma ray and the crystal can be determined by processing the voltage signals from the photomultipliers; in simple terms, the location can be found by weighting the position of each photomultiplier tube by the strength of its signal, and then calculating a mean position from the weighted positions. The total sum of the voltages from each photomultiplier is proportional to the energy of the gamma ray interaction, thus allowing discrimination between different isotopes or between scattered and direct photons.

2.1.3 Spatial resolution:

In order to obtain spatial information about the gamma emissions from an imaging subject (e.g. aperson's heart muscle cells which have absorbed an intravenous injected radioactive, usually thallium-201 or technetium-99m, medicinal imaging agent) a method of correlating the detected photons with their point of origin is required.

The conventional method is to place a collimator over the detection crystal/PMT array. The collimator consists of a thick sheet of lead, typically 1-3 inches thick, with thousands of adjacent holes through it. The individual holes limit photons which

can be detected by the crystal to a cone; the point of the cone is at the midline center of any given hole and extends from the collimator surface outward. However, the collimator is also one of the sources of blurring within the image; lead does not totally attenuate incident gamma photons, there can be some crosstalk between holes.

Unlike a lens, as used in visible light cameras, the collimator attenuates most (>99%) of incident photons and thus greatly limits the sensitivity of the camera system. Large amounts of radiation must be present so as to provide enough exposure for the camera system to detect sufficient scintillation dots to form a picture. Other methods of image localization (pinhole, rotating slat collimator with CZT (Gagnon & Matthews) and others) have been proposed and tested; however, none have entered widespread routine clinical use.

The best current camera system designs can differentiate two separate point sources of gamma photons located a minimum of 1.8 cm apart, at 5 cm away from the camera face. Spatial resolution decreases rapidly at increasing distances from the camera face. This limits the spatial accuracy of the computer image: it is a fuzzy image made up of many dots of detected but not precisely located scintillation. This is a major limitation for heart muscle imaging systems; the thickest normal heart muscle in the left ventricle is about 1.2 cm and most of the left ventricle muscle is about 0.8 cm, always moving and much of it beyond 5 cm from the collimator face. To help compensate, better

imaging systems limit scintillation counting to a portion of the heart contraction cycle, called gating, however this further limits system sensitivity.

2.2 Heart scans procedures:

2.2.1 Nuclear Heart Scan:

A nuclear heart scan is a test that provides important information about the health of your heart. For this test, a safe, radioactive substance called a tracer is injected into your bloodstream through a vein. The tracer travels to your heart and releases energy. Special cameras outside of your body detect the energy and use it to create pictures of your heart.

Nuclear heart scans are used for three main purposes:

To check how blood is flowing to the heart muscle. If part of the heart muscle isn't getting blood, it may be a sign of coronary heart disease (CHD). CHD can lead to chest pain called angina (an-JI-nuh or AN-juh-nuh), a heart attack, and other heart problems. When a nuclear heart scan is done for this purpose, it's called myocardial perfusion scanning.

To look for damaged heart muscle. Damage might be the result of a previous heart attack, injury, infection, or medicine. When a nuclear heart scan is done for this purpose, it's called myocardial viability testing.

To see how well your heart pumps blood to your body. When a nuclear heart scan is done for this purpose, it's called ventricular function scanning. Usually, two sets of pictures are taken during a

nuclear heart scan. The first set is taken right after a stress test, while your heart is beating fast.

During a stress test, you exercise to make your heart work hard and beat fast. If you can't exercise, you might be given medicine to increase your heart rate. This is called a pharmacological (FAR-ma-ko-LOJ-ih-kal) stress test. The second set of pictures is taken later, while your heart is at rest and beating at a normal rate.

2.2.2 Types of Nuclear Heart Scans:

The two main types of nuclear heart scans are single photon emission computed tomography (SPECT) and cardiac positron emission tomography (PET).

2.2.2.1 Single Photon Emission Computed Tomography:

Doctors use SPECT to help diagnose coronary heart disease (CHD). Combining SPECT with a stress test can show problems with blood flow to the heart. Sometimes doctors can detect these problems only when the heart is working hard and beating fast.

Doctors also use SPECT to look for areas of damaged or dead heart muscle tissue. These areas might be the result of a previous heart attack or other cause.

SPECT also can show how well the heart's lower left chamber (left ventricle) pumps blood to the body. Weak pumping ability might be the result of a heart attack, heart failure, and other causes. Tracers commonly used during SPECT include thallium-201, technetium-99m sestamibi (Cardiolite®), and technetium-99m tetrofosmin (Myoview™).

2.2.2.2 Positron Emission Tomography:

Doctors can use PET for the same purposes as SPECT—to diagnose CHD, check for damaged or dead heart muscle tissue, and check the heart's pumping strength.

Compared with SPECT, PET takes a clearer picture through thick layers of tissue (such as abdominal or breast tissue). PET also is better at showing whether CHD is affecting more than one of your heart's blood vessels.

Right now, however, there's no clear advantage of using one scan over the other in all situations. Research into advances in both SPECT and PET is ongoing.

PET uses different tracers than SPECT. Other Names for a Nuclear Heart Scan Nuclear stress test, SPECT scan, PET scan and Radionuclide scan

2.2.2.3 Expectation before a Nuclear Heart Scan:

A nuclear heart scan can take a lot of time. Most scans take between 2–5 hours, especially if your doctor needs two sets of pictures.

Discuss with your doctor how a nuclear heart scan is done. Talk with him or her about your overall health, including health problems such as asthma, COPD (chronic obstructive pulmonary disease), diabetes, and kidney disease. If you have lung disease or diabetes, your doctor will give you special instructions before the nuclear heart scan.

If you're having a stress test as part of your nuclear heart scan, wear comfortable walking shoes and loose-fitting clothes for the test. You may be asked to wear a hospital gown during the test. Let your doctor know about any medicines you take, including prescription and over-the-counter medicines, vitamins, minerals, and other supplements. Some medicines and supplements can interfere with the medicines that might be used during the stress test to raise your heart rate.

2.2.2.4 Expectation During a Nuclear Heart Scan:

Many nuclear medicine centers are located in hospitals. A doctor who has special training in nuclear heart scans—a cardiologist or radiologist—will oversee the test.

Cardiologists are doctors who specialize in diagnosing and treating heart problems. Radiologists are doctors who have special training in medical imaging techniques.

Before the test begins, the doctor or a technician will use a needle to insert an intravenous (IV) line into a vein in your arm. Through this IV line, he or she will put radioactive tracer into your bloodstream at the right time.

You also will have EKG (electrocardiogram) patches attached to your body to check your heart rate during the test. (An EKG is a simple test that detects and records the heart's electrical activity.)

2.2.2.4 During the Stress Test:

If you're having an exercise stress test as part of your nuclear scan, you'll walk on a treadmill or pedal a stationary bike. During this time, you'll be attached to EKG and blood pressure monitors.

Your doctor will ask you to exercise until you're too tired to continue, short of breath, or having chest or leg pain. You can expect that your heart will beat faster, you'll breathe faster, your blood pressure will increase, and you'll sweat.

Tell your doctor if you have any chest, arm, or jaw pain or discomfort. Also, report any dizziness, light-headedness, or other unusual symptoms.

If you're unable to exercise, your doctor may give you medicine to increase your heart rate. This is called a pharmacological stress test. The medicine might make you feel anxious, sick, dizzy, or shaky for a short time. If the side effects are severe, your doctor may give you other medicine to relieve the symptoms. Before the exercise or pharmacological stress test ends, the tracer is injected through the IV line.

2.2.2.5 During the Nuclear Heart Scan:

The nuclear heart scan will start shortly after the stress test. You'll lie very still on a padded table. The nuclear heart scan camera, called a gamma camera, is enclosed in metal housing. The camera can be put in several positions around your body as you lie on the padded table.

For some nuclear heart scans, the metal housing is shaped like a doughnut (with a hole in the middle). You lie on a table that slowly

moves through the hole. A computer nearby or in another room collects pictures of your heart .

Usually, two sets of pictures are taken. One will be taken right after the stress test and the other will be taken after a period of rest. The pictures might be taken all in 1 day or over 2 days. Each set of pictures takes about 15–30 minutes.

Some people find it hard to stay in one position during the test. Others may feel anxious while lying in the doughnut-shaped scanner. The table may feel hard, and the room may feel chilly because of the air conditioning needed to maintain the machines.

Let your doctor or technician know how you're feeling during the test so he or she can respond as needed.

2.2.2.6 Expectation After a Nuclear Heart Scan:

Your doctor may ask you to return to the nuclear medicine center on a second day for more pictures. Outpatients will be allowed to go home after the scan or leave the nuclear medicine center between the two scans.

Most people can go back to their daily routines after a nuclear heart scan. The radioactivity will naturally leave your body in your urine or stool. It's helpful to drink plenty of fluids after the test, as your doctor advises.

The cardiologist or radiologist will read and interpret the results of your test. He or she will report the results to your doctor, who will contact you to discuss them. Or, the cardiologist or radiologist may contact you directly to discuss the results.

2.3Radio nuclides in heart scan:

2.3.1Technetium Heart Scan:

The technetium heart scan is a noninvasive nuclear scan that uses a radioactive isotope called Technetium to evaluate blood flow after a heart attack.

2.3.2 Purpose:

The technetium heart scan is used to evaluate the heart after a heart attack. It can confirm that a patient had a heart attack when the symptoms and pain usually associated with a heart attack were not present; identify the size and location of the heart attack; and provide information useful in determining the patient's post-heart attack prognosis. The scan is most useful when the electrocardiogram and cardiac enzyme studies do not provide definitive results—after heart surgery, for example, or when chest pain occurred more than 48 hours before the patient was examined. It is also used to evaluate the heart before and after heart surgery.

2.3.3 Precautions:

Pregnant women and those who are breastfeeding should not be exposed to technetium.

2.3.4 Description:

The technetium heart scan is a nuclear heart scan, which means that it involves the use of a radioactive isotope which targets the

heart, and a radionuclide detector that traces the absorption of the radioactive isotope. The isotope is injected into a vein and absorbed by healthy tissue at a known rate during a certain time period. The radionuclide detector, in this case a gamma scintillation camera, picks up the gamma rays emitted by the isotope. The technetium heart scan uses technetium Tc-99m stannous pyrophosphate (usually called technetium), a mildly radioactive isotope that binds to calcium. After a heart attack, tiny calcium deposits appear on diseased heart valves and damaged heart tissue. These deposits appear within 12 hours of the heart attack. They are generally seen two to three days after the heart attack and are usually gone within one to two weeks. In some patients, they can be seen for several months. After the technetium is injected into a blood vessel in the arm, it accumulates in heart tissue that has been damaged, leaving "hot spots" that can be detected by the scintillation camera. The technetium heart scan provides better image quality than commonly used radioactive agents such as thallium, because it has a shorter half-life and can thus be given in larger doses.

During the test, the patient lies motionless on the test table. Electrocardiogram electrodes are placed on the patient's body for continuous monitoring during the test. The test table is rotated so that different views of the heart can be scanned. The camera, which looks like an x-ray machine and is suspended above the table, moves back and forth over the patient. It displays a series

of images of technetium's movement through the heart and records them on a computer for later analysis.

The test is usually performed at least 12 hours after a suspected heart attack, but it can also be done during triage of a patient who goes to a hospital emergency room with chest pain but does not appear to have had a heart attack. Recent clinical studies demonstrate that technetium heart scans are very accurate in detecting heart attacks while the patient is experiencing chest pain. They are far more accurate than electrocardiogram findings.

The technetium heart scan is usually performed in a hospital's nuclear medicine department but it can be done at the patient's bedside during a heart attack if the equipment is available. The scan is done two to three hours after the technetium is injected. Scans are usually done with the patient in several positions, with each scan taking 10 minutes. The entire test takes about 30 minutes to an hour. The scan is usually repeated over several weeks to determine if any further damage has been done to the heart. The test is also called technetium 99m pyrophosphate scintigraphy, hot-spot myocardial imaging, infarct avid imaging, or myocardial infarction scan. The technetium heart scan is not dangerous. The technetium is completely gone from the body within a few days of the test. The scan itself exposes the patient to about the same amount of radiation as a chest x-ray.The patient can resume normal activities immediately after the test.

2.3.5 Preparation:

Two to three hours before the scan, technetium is injected into a vein in the patient's forearm.

Normal results:

If the technetium heart scan is normal, no technetium will show up in the heart.

Abnormal results:

In an abnormal technetium heart scan, hot spots reveal damage to the heart. The larger the hot spots, the poorer the patient's prognosis.

2.4 Risks of a Nuclear Heart Scan:

The radioactive tracer used during nuclear heart scanning exposes the body to a very small amount of radiation. No long-term effects have been reported from these doses.

Radiation dose might be a concern for people who need multiple scans. However, advances in hardware and software may greatly reduce the radiation dose people receive. Some people are allergic to the radioactive tracer, but this is rare.

If you have coronary heart disease, you may have chest pain during the stress test while you're exercising or taking medicine to raise your heart rate. Medicine can relieve this symptom. If you're pregnant, tell your doctor or technician before the scan. It might be postponed until after the pregnancy.

2.5 Radiation dose quantities and units:

During the early days of radiological experience there was no precise unit of radiation does that was suitable either for radiation protection or for radiation therapy. For purposes the radiation protection, a common “dosimeter” was a piece of dental film with a paper clip attached. A daily exposure great enough to just produce a detectable shadow was considered a maximum permissible dose. For greater does and for therapy purposes the dose unit was frequently the “skin erythema unit”. Because of the great energy dependence of the dose units could be biologically meaningful or useful either in quantitative study of the biological effects of radiation or for radiation protection purposes. Furthermore, since the fraction of the energy in a radiation field that is absorbed by the body is dependent, it is necessary to distinguish between radiation exposure and radiation absorbed dose. (ICRP 60: 1990 recommendation)

2.5.1 Absorbed dose:

Absorbed dose is a non-stochastic quantity, defined as the expectation value of the energy imparted to matter, ε, per unit mass of tissue at the point of interest dm.

$$D=d\varepsilon/dm \qquad 2.1$$

Radiation damage depends on the absorption of energy from the radiation and is approximately proportional to the concentration of absorbed energy in tissue. (ICRP 60: 1990 recommendation)

2.5.1.1 Gray:

The basic unit of radiation dose called the gray (Gy) and is defined as: one gray is an absorbed radiation dose of one joule per kilogram. The gray is universal

applicable to all types of ionizing radiation dosimetry. (ICRP 60: 1990 recommendation)

2.5.1.2 Rad:

Before the universal absorption of the SI units, radiation dose was measured by a unit called the rad (Radiation Absorbed Dose). One rad is an absorbed radiation dose of 100 ergs per gram.

$$1 \text{ rad} = 100 \text{ergs/g} \qquad 2.2$$

Since 1 J=10^7 ergs, and since 1kg=1000g, 1Gy=100 rads.

Although the gray is the newer unit, and will eventually replace the rad. (ICRP 60: 1990 recommendation)

2.5.1.3 kerma:

Kerma is a non-stochasitc quantity, defined as the expectation value of the energy transferred (εtr) by uncharged particles (e.g. ohotons or neutrons) to charge particles per unit mass at the point of interest dm.

$$K = d\varepsilon \text{ tr}/dm \qquad 2.3$$

Kerma has been defined as, and is an acronym for, the sum of the kinetic energies of all those primary charged particles released by uncharged particles (here photons) per unit mass (Kinetic Energy Released per unit MAss) the unit of kerma is grey (Gy), where 1 Gy=1j kg-1.

In a photon field, the kerma at the point of interest is expressed as

$$K = \int_{E=0}^{E\,max} \Psi(E) \frac{\mu tr}{p} \qquad 2.4$$

Where Ψ (E) is the distribution of photon energy fluence and $\frac{\mu tr}{p}$ is the mass energy –transfer (Attix, 1986). Photon energy fluence is defined as the product photon fluence and energy E.

Kerma is greater than absorbed dose by a factor of 1/ (1-g). this relation is valid only for irradiation in the condition of charged particle equilibrium i,e when the number and energies of charged particles leaving is equal to the number and energies of particles entering this volume.

$$D = (1-g)\ K \qquad 2.5$$

The factor g represent the average fraction of the kinetic energy of secondary charged particles (produced in all types of interactions) that is subsequently lost in radiative (photon emitting) energy-loss processes as the particles slow to rest in the medium. (ICRP 60: 1990 recommendation)

2.5.1.4 Exposure:

Exposure is a radiation quantity referring to the intensity of radiation for external radiation of any give energy flux, the absorbed to any point with in an organism depends on the types and the energy of radiation, the depth within the organism of the point at which the absorbed dose is required, and elementary constitution of the absorbing medium at this point. The exposure unit is a measure of photon flux, and is related to the amount of energy transferred from the X-ray field to a unit mass of air. One exposure unit is defined as that quantity of x-or gamma radiation that produces in air, ions carrying 1 coulomb of charge (of either sign) per Kg air.

1x unit= 1c/Kg air.

The exposure unit is based on ionization of air because of the relative ease with which radiation induced ionization can be measured. The exposure unit bay be converted in to more fundamental unit of energy absorption per unit mass of air by using the charge on a single ion is 1.6x10-19 coulombs and that the average energy dissipated in the production of a single ion pair in air is 34ev (Cecili Godderidge 1995).

Therefore:

1x unit= $\frac{c}{Kg\,air}$ x $\frac{1\,ion}{1.6x10-19}$ x 34 eV/ion x 1.6x10-19 j/ev x 1Gy/j/Kg=34Gy (in air)

2.5.1.5 Equivalent dose:

Equal doses of all types of ionizing radiation are not equally harmful. Alpha particles produce greater harm than do beta particles, gamma rays and x rays for a given absorbed does. To account for this difference, radiation does is expressed as equivalent does. The equivalent does (HT) is a measure of the radiation does to tissue where an attempt has been made to allow for the different relative Biological effects of different types of ionizing radiation. Equivalent does is therefore a less fundamental quantity than radiation absorbed does, but is more biologically significant. Equivalent does has units of Sieverts (Sv). Another unit, rontgen equivalent man (REM or rem), is still in common use in the US, although regulatory and advisory bodies are encouraging transition to Sieverts (100 Rontgen equivalent man=100 REM= 1 sievert.).(www.nrc.gov\reading-rm\doc, 2007)

Equivalent does (HT) is calculated by multiplying the absorbed does to the organ or tissue (DT) with the radiation weighting factor, WR. This factor is selected for the type and energy of the radiation incident on the body, or in the case of sources

within the body, emitted by the source. The value of WR is 1 for x-rays, gamma rays and beta particles, but higher for protons, neutrons, alpha particles etc.

$H_{T,R} = W_R \times D_{T,R}$ 2.6

Where $H_{T,R}$ = equivalent dose to tissue T from radiation R

$D_{T,R}$ = absorbed dose D (in grays) to tissue T from radiation R

The dose in Sv is equal to "absorbed dose" multiplied by a "radiation weighting factor" (WR – see Table 2.1 below). Prior to 1990, this weight factor was referred to as Quality Factor (QF).

Table 2.1 Recommended Radiation Weight Factors (ICRP 60: 1990 recommendations).

Radiation weighting factor , WR	Type and energy range
1	Gamma rays and X-rays
1	Beta particles
5	Neutrons , energy < 10 KeV
10	>10 KeV to 100 KeV
20	>100 KeV to 2MeV
10	>2MeV to 20 MeV
5	> 20MeV
5	Alpha particles

2.5.1.6 Effective dose:

Effective dose equivalent (Now replaced by Effective Dose) is used to compare radiation doses on different body parts on an equivalent basis because radiation

does not affect different parts in the same way. The effective dose is the sum of weighted equivalent doses in all the organs and tissues of the body.

Effective dose = sum of [organ doses x tissue weighting factor].

The effective dose (E) to an individual is found by calculating a weighted average of the equivalent dose (H) to different body tissues, with the weighting factors (W) designed to reflect the different radio sensitivities of the tissues:

$$E = \sum_i H \quad i \; Wi \qquad\qquad 2.7$$

The unit for effective dose is the sievert (Sv) (ICRP 60: 1990 recommendation).

Table 2.2 Tissue Weighting Factors for Individual Tissue and Organ (ICRP 60: 1990 recommendation).

Tissue Weighting Factor (WT)	Tissue or Organ
0.20	Gonads (testes or ovaries)
0.12	Red bone marrow
0.12	Colon
0.12	Lung
0.12	Stomach
0.05	Bladder
0.05	Breast
0.05	Liver
0.05	Esophagus
0.05	Thyroid gland
0.01	Skin
0.01	Bone surfaces
0.05	Remainder**
1.00	Whole body

One Sievert is a large dose. The effects of being exposed to large doses of radiation at one time (a cute exposure) vary with the dose. Here are some Examples:

10 Sv - Risk of death within days or weeks.

1 mSv- Risk of cancer later in life (5 in 1000).

100 mSv-TLV for annual dose for radiation workers in any one year.

20 mSv-TLV for annual average dose, averaged over five years.

What are the limits of exposure to radiation? The Limits Values are used in many jurisdictions occupational exposure.

2.6 Limits or guidelines:

20 mSv-limit value for average annual dose for radiation workers, average over five years.

1 mSv Recommended annual dose limits for general public (ICRP-International Commission on radiological protection).

2.7 Methods of dose estimation in nuclear medicine:

Fortunately, the only method we need to know is the MIRD method, and only in general terms.

The Nuclear Medicine Society (NMS) has a committee known as the Medical Internal Radiation Dose (MIRD) Committee. They have developed a method of estimating the dose delivered to a target organ.

This method relies on determining the radioactive decay occurring in a target organ (and related organs), calculating how much energy is deposited in the target organ from the organ itself and neighbouring structures, and determining the final dose within the target organ. A warning: This is very hard to comprehend initially (well at least I found it tricky) but once I worked through it the sense behind it all came out....

Definitions:

Target Organ (T):

The target organ is the organ in which the dose is to be determined.

Source Organ (S):

The source organ is the point of origin of the ionising radiation. The source organ may also be the target organ.

Mean Energy Per Transition:

The mean energy per transition ($\triangle$) released in the source organ is equal to the mean particle energy (E) multiplied by the average number of particles per transition (n), together with a conversion factor K. This gives the first equation:

$\triangle = KEn$ (1)

I'm not sure what the K factor actually does.

Cumulated Activity:

The **cumulated activity** $\tilde{A}$ is the total number of transitions that occur in a target organ from time = 0 to time = T.

$$\tilde{A} = \int_0^T A(t).dt \quad (2)$$

The function A(t) is:

$$A(t) = A(0).\exp(-\lambda_e .t) \quad (3)$$

This all gets very complicated unless you take the time *T* to be ∞, in which case it all simplifies down to:

$$\tilde{A} = 1.44 T_e A(0) \quad (4)$$

Where T_e is the effective half life and A(0) is the initial activity in the organ in question (see below).

Inital Activity in the Organ A(0) **:**

A(0) means something different in the MIRD calculation. Instead of initial activity, A(0) stands for the initial activity in the organ in question. It is equal to:

$$A(0) = f_2 .q(0) \quad (5)$$

Where q(0) is the total activity within the body, and f_2 is the fraction of the activity present in the

source organ.

Total energy emitted by source organ:

The total energy emitted by the source organ is the product of the mean energy per transition $\triangle$ multiplied by the cumulated activity $\tilde{A}$. Furthermore, only a fraction *f* of the energy emitted by the source organ will be deposited in the target organ. The mass *m* of the target organ is also used to determine the mean dose $\bar{D}$.

$$\bar{D} = \tilde{A} . \triangle . f \, m \quad (6)$$

Mean dose to target organ per cumulated activity of the source organ:

Almost there! This is where MIRD becomes simple!

The mean dose to target organ per cumulated activity of the source organ is written as [[$ S

(T \leftarrow S)]] and is equal to:

$$S(T \leftarrow S) = \triangle . f \, m \quad (7)$$

Final equation:+

Substituting equation 7 into equation 6, we end up with:

$$\bar{D} = \tilde{A} \times S(T \leftarrow S) \quad (8)$$

The $\tilde{A}$ value is specific for the fraction of dose within the source organ, and the effective half life of

the radiopharmaceutical.

The S(T←S) value is specific for the energy and range of the released particles and the relationship

of the source and target organs. MIRD have tabulated a list of S(T←S) values for different

radionuclides and different organs.

Use of MIRD:

MIRD allows the dose to a target organ to be determined for the nearby source organs. It splits the calculation of dose into two factors:

The pharmacokinetics of the radiopharmaceutical the physical properties of the radiation and the organ structure Therefore, despite being quite difficult to work through initially, the MIRD formula simplifies the calculation of dose to target organs.

2.8 Literature review:

In Mexico by SPECT has a high sensitivity for the diagnosis of coronary artery disease. Dual isotope protocol using rest thallium and stress MIBI was introduced in of both radiotracers for the study of myocardial perfusion. We present our experience of the

first three years. One thousand six hundred patients were studied with suspected myocardial ischemia; 288 were excluded because of an absence of a proper follow up. In 895 of the 1312 patients a coronariography was performed. Images were evaluated by dividing the heart in 20 segments using a 5 points scale (0 = normal to 4 = absence of perfusion). It was considered a perfusion defect when a segment had a score greater or equal to 2 and the SPECT study was considered abnormal if two or more segments had a MIBI stress score equal or greater than 2. The global sensitivity for diagnosis of ischemia was 96.28%. Dual isotope method is appropriate for the diagnosis of ischemic heart disease. It has a high sensitivity and specificity for the recognition of global coronary disease and for specific coronary territories. This work constitutes the greatest series in Latin America that uses this diagnosis method.

In USA Gated SPECT imaging has allowed the simultaneous assessment of both perfusion and function through one study. The popularity of this is amply shown by the unprecedented growth of this imaging modality throughout the country. In addition to the benefits that ventricular function adds to perfusion, gated SPECT imaging also adds to the specificity of perfusion imaging. With recent studies showing the benefit of medical therapy to interventional approaches for the treatment of patients with angina, in particular, patients with chronic stable angina, there has been an increased dependence on noninvasive imaging to assess their ischemic burden. Perfusion, with technetium-

99msestamibi SPECT imaging together with gated SPECT imaging has been the modality of choice in the majority of cases because of the ease of performance of these studies and the increased information provided. This has in large part been attributable to the ability of gated SPECT imaging to provide functional data, significantly increasing the use of radionuclide perfusion imaging. This article reviews the method of acquisition, validation, clinical use, and the newer advances of gated SPECT imaging. It gives an appreciation of the benefit that gated SPECT imaging has added in terms

of risk stratification and prognosis in many cardiac patients. Under the more recent uses are myocardial viability and the increased utility of gating in this scenario, ischemic versus no ischemic cardiomyopathies, and the quandary that this testing poses to physicians and the dilemma of gated thallium imaging with its inferior image quality.

Materials and Methods

3.1 Introduction:

Nuclear medicine involves the use of small amounts of radioactive materials (or tracers) to help diagnose and treat a variety of diseases. Nuclear medicine determines the cause of the medical problem based on the function of the organ, tissue or bone. This is how nuclear medicine differs from an x-ray, ultrasound or any other diagnostic test that determines the presence of disease based on structural appearance.

in this study aims to evaluate of patient dose in heart scan and estimate the radiation dose that is given to the patient and reduce the radiation hazard in the diagnosis of heart disease using Technetium-99m in the presence of a gamma camera and access to the correct results .the data used in study was collected from alnilein medical diagnostic center in Khartoum.

3.2 Gamma camera Machine:

Used in this study, a gamma camera of the type (MIE) for data collection and includes the following specifications:

Type: orbiter 37(single head 37 PMTs/FOV387mm)

Camera console: scintron VI-VME

Patient bed: carbon fiber pallet

Collimatter: low energy general purpose

Manuals: hard/electron copy, Printer: HP2300business inkjet

3.3 Patient data:

Patient population in this study include body characteristic (age, weight, height and body mass index (BMI)), and data of radioactive source include(material, activity, half life, quantity, manufacturer, start time, end time, time of injections, scan time, end of scan time and patient instructions)

3.4 Data collection:

We collect data in this study in Khartoum state from alnileen diagnostic center from May 2012 to July 2012.

3.5 Patient preparation:

No Caffeine for 24 Hours prior to your Myocardial Perfusion Scan (i.e. No coffee, tea, chocolate, Cola or energy drinks or any other beverages or food containing caffeine).

3.6 Procedure of examination:

Stress and rest studies are usually performed using a 1-day protocol this requires administration of a low dose, one-third of the total dose or 8–12 mCi, for the first study (gated image acquired for 20 to 30 image) and a larger dose, two thirds of the total dose or 20–30 mCi, (gated image acquired for 20 to 30 image) for the second study and waiting as long as possible between studies, usually 1.5–2.5 h, to allow for physical decay of Tc- 99m.

3.7 Method of dose calculation:

According to a special report published in Radiology, in 2008 , Nuclear Medicine effective dose can be calculated by using an administered activity schedule based on body surface area in relation to adult reference values of 1.73 m2 surface area and 1100 MBq administered activity, as (0.0079 for rest study and 0.009 for stress) msv per MBq .

3.8Analysis of data:

All recorded information after a specific test for the screening and follow the method of calculating the dose by radioactive material and used the data statistical analysis program (SPSS) and Microsoft excel for analysis.

Results

4.1 Introduction

The results were tabulated in the Tables (mean ± standard deviation (std)) and the range of the readings in parenthesis (min-max). The dose values in diagnostic radiology are small, therefore the dose were presented in MBq. The mean and the standard deviation were calculated using the excel software. For dose calculation, patient individual exposure parameters were recorded (activity and weight).

Table 4.1 shows (Mean ± SD range) for patient effective dose and body characteristics; (weight, age, height, and effective dose) in heart Examination.

Action	Mean(average ±std)	Max and MIN
Weight (kg)	95.4±14.6	70-133
Age(year)	60.1±8.2	72 -37
High (cm)	169.4±6.04	156-176
Activity(mci)	524.5±102.9	753.2-370
Effective dose (Mpq)	(4.47±0.98).	(3.33- 6.77)

figure 4.1 direct linear association between the patient weight and effective dose with a coefficient of 0.04msv/kg i.e for each kilogram of weight the effective dose increased by 0.04 msv

Figure4.2: direct linear association between the BMI and effective dose with a coefficient of 4.05 msv

Figure (4.3) direct linear association between the patient hieght and effective dose with a coefficient of 0.03msv/cm

Figure (4.4) direct linear association between the patient age and effective dose with a coefficient of 0.02msv/cm

Figure (4.5) direct linear association between the Activity and effective dose with a coefficient of 0.34msv/cm

DISCUSSION, CONCLUSION and Recommendations

5.1 DISCUSSION:

The general objective of this study was to Measure the patient dose in heart scintgraphy examination to evaluate the risk of radiation .the data used in study was collected from alnilein medical diagnostic center in Khartoum and also in this study, the use of two types of examination of the so-called Stress and rest test. studies are usually performed using a 1-day protocol this requires administration of a low dose, one-third of the total dose or 8–12 mCi, for the first study (gated image acquired for 20 to 30 image) and a larger dose, two thirds of the total dose or 20–30 mCi, (gated image acquired for 20 to 30 image) for the second study and waiting as long as possible between studies, usually 1.5–2.5 h, to allow for physical decay of Tc- 99m.

In this study, data were collected from about 25 patients and calculate the radiation dose by injection patients element technetium and compare the results with previous studies in Mexico by SPECT has a high sensitivity for the diagnosis of coronary artery disease. Dual isotope protocol using rest thallium and stress MIBI was introduced in of both radiotracers for the study of myocardial perfusion and The study confirmed that there is a high sensitivity in the diagnosis of coronary artery disease by element thallium compared to the diagnosis of heart disease by element technetium and also in USA there has been an increased dependence on noninvasive imaging to assess their ischemic burden. Perfusion, with technetium-99msestamibi SPECT imaging together with gated SPECT imaging has been the modality of choice in the majority of cases because of the ease of

performance of these studies and the increased information provided.

The acquired the result from Nilien Center proved that there is a significant exposure to the radiation dose, as especially for patients with great weight where the average patient weight was (95± 14.66)kg(70-133)kg ,for activity and effective dose it was (524.45±102.88) Mpq and (4.47±0.98)msv respectively. generally there is a direct linear association between the patient weight and effective dose with a coefficient of 0.04msv/kg i.e for each kilogram of weight the effective dose increased by 0.04 msv as show (4-1).

And The rest examination weight (96± 13.06), activity (508.38 ±69.07), effective dose (4.01±0.55) and stress examination weight (94.91 ± 17.69), activity (13.55 ± 2.52), effective dose (4.51± 0.84).and addition to maximum effective dose 6.77, minimum effective dose 3.33.

5.2 CONCLUSION:

This study aims to measurement of patient dose in heart scan and estimates the radiation dose that is given to the patient and reduces the radiation hazard in the diagnosis of heart disease using Technetium-99m in the presence of a gamma camera and access to the correct results. Used in this study, a gamma camera of the type (MIE) for data collection.

The results were by calculating the radiation dose and the patient's weight to get the effective dose and the average results were as follows: (4.47±0.98) and patient weight (95± 14.66). and effective dose calculated by using an administered activity schedule based on body surface area in relation to adult reference values of 1.73 m2 surface area and 1100 MBq administered activity, as (0.0079 for rest study and 0.009 for stress) msv per MBq . According to a special report published in Radiology, in 2008.

5.3Recommendations:

From the present study, you should:

- reduce the dose of radiation to reduce the danger of radioactivity and dose proportional to the age and weight of the patient.
- Recommended to measure the dose of radiation in other organs in the measurement of heart scan and exposure to what extent was to protect patients.
- Researchers recommended the work of this study again in Sudan and compared with previous studies.

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5.7Appendixes:

Age	weight	height	Activity	activity/Mbq	effective dose
52	133	160	19	703	5.5537
63	105	156	15	555	4.3845
61	92	172	13.14286	486.2857	3.841657
57	90	175	12.85714	475.7143	3.758143
66	90	170	12.85714	475.7143	3.758143
68	90	176	12.85714	475.7143	3.758143
68	90	175	12.85714	475.7143	3.758143
62	97	174	13.85714	512.7143	4.050443
57	91	174	13	481	3.7999
56	90	171	12.85714	475.7143	3.758143
37	90	172	12.85714	475.7143	3.758143
62	113	170	16.14286	597.2857	5.375571

52	133	160	19	703	6.327
61	105	156	15	555	4.995
58	96	175	13.71429	507.4286	4.566857
55	97	173	13.85714	512.7143	4.614429
69	97	170	13.85714	512.7143	4.614429
71	90	173	12.85714	475.7143	4.281429
64	99	164	14.14286	523.2857	4.709571
62	91	170	13	481	4.329
64	75	166	10.71429	396.4286	3.567857
60	70	164	10	370	3.33
42	73	173	10.42857	385.8571	3.472714
72	95	173	20.35714	753.2143	6.778929
63	94	174	20.14286	745.2858	6.707572