

SUDAN UNIVERSITY OF SCIENCE & TECHNOLOGY
College OF graduate STUDIES

**Measurement of Radiation Dose Received by the Nuclear
Medicine Technologist During the Mo99-TC99m Generator
Elution**

قياس الجرعة الاشعاعية التي يتلقاها تقني الطب النووي اثناء استحلاب مولد
الموليبدينوم 99-تكنيشيوم 99م

*Thesis submitted for partial fulfillment of M.Sc. degree in nuclear
medicine Technology*

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الآية

قال تعالى:

(الله نور السموات والأرض، مثل نوره كمشكاة فيها مصباح، المصباح في زجاجة، الزجاج كأنها كوكب دري يوقد من شجرة مباركة زيتونة لا شرقية ولا غربية، يكاد زيتها يضيء ولو لم تمسسه نار، نور على نور، يهدي الله لنوره من يشاء، ويضرب الله الأمثال للناس والله بكل شيء عليم)

سورة النور الآية (35)

Dedication

To whom all the world languages don't find suitable words to write
about

The heart, the soul, the beginning and the end

To Saida Mohamed Salih

My mother

To the man who has made his fingers candles to light my way
my support, help and my pleasure,

To my father.

&

To my sisters, son and daughter.

I dedicate this humble study.

Acknowledgment

I pay my thanks for help, support and encouragement, to God firstly, Who blessed me in each stepSpecial. and great thanks to my supervisor Dr. Salah Ali Fadllalh who kept on pushing, guiding, advising and supervising till the end of my research.

To all nuclear medicine technologists in Fedil Specialized Hospital Who helped me in collecting my data, and to everyone who helped me in presenting my research in its last form.

Last but not leastto every sweet person who assisted and helped me by words, deeds and even thoughts,especially my friends and colleagues.

Abstract

This study was performed in the hot lab of nuclear medicine department in Fedail Specialized Hospital, (Khartoum) over eleven days extending from December 19th to January 30th 2016. TC99m generator was selected for the study. Measurements of dose were performed in nine points distributed in hot lab, measured by high sensitive survey meter and dose calibrator.

The results showed that the hand exposure was 2.9msv during elution (eleven days)The whole body exposure was 0.066 mSv during elution.

The summation of doses during elution led to exposure rate of 2.9 mSv at point one which was within the range of permissible dose of the hands and represented 3.8% of the maximum permissible dose (75 rem in one year) for one generator and the number of generators per year in Fedail Specialized Hospital is at the average of thirty. If only one technologist eluted all generators per year he/she would exceed the maximum permissible dose by 39%

However, the summation of the whole body exposure outside the exhaust fan (the dose at point 5) for 11 days was 0.054 msv, Which was in the range of the permissible doses of the workers and represented 0.0732% of the maximum permissible dose, and for the thirty generators it represented 2.19% of maximum permissible dose. The measurements at these points was within the international permissible levels.

ملخص الدراسة

هذه الدراسة اجريت في المعمل الاشعاعي بقسم الطب النووي بمستشفى فضيل التخصصي في الفترة من 19 ديسمبر الي 30 ديسمبر علي مولد التكنيشيوم 99م الذي اختير للدراسة وهناك 9 نقاط موزعة في المعمل الاشعاعي وقيست بواسطة جهاز المسح الاشعاعي عالي الحساسية.

واوضحت النتائج ان اعلي جرعة تعرضت لها الايدي في (تلامس مباشر) هي 2.9 ملي سيفرت خلال الاستحلاب وكان التعرض لكل الجسم 0.066 ملي سيفرت خلال الاستحلاب ومجموع الجرعات خلال الاستحلاب يقود الي معدل تعرض يساوي 2.9 ملي سيفرت في النقطة الاولي وهو يقع ضمن المعدل المسموح به عالميا ويمثل 3.8% للمولد الواحد ومتوسط عدد المولدات في السنة في مستشفى فضيل التخصصي هو 30 مولدا واذا استحلب تقني واحد كل المولدات في العام فسوف يتجاوز الحد المسموح به عالميا بنسبة 39%

وكان المجموع الكلي للجرعة الدرع الواقي (جرعة النقطة 5) للاحد عشر يوما هو 0.054 ملي سيفرت وهو ضمن الحد المسموح به عالميا للعاملين ويمثل 0.0732% من الحد الاقصي المسموح به وللمولدات الثلاثين تمثل 2.19% من الجرعة المسموح بها. عموما اوضحت الدراسة ان القياسات علي جميع النقاط كانت في الحدود المسموح بها عالميا.

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List of abbreviation

NM	Nuclear medicine
Sv	sivert
Bq	bequral
Gp	Gaga bequral
FSH	Fedail specialized hospital
Cm	centi meter
DNA	deoxyribonuclic acid
ALARA	As low as reasonable achievable
OH	Hydroxy free radical
Lab	labrotary
TC ^{99m}	Tecinitium-99m
CPS	count per seconds
Dpm	disintegration per minute
GM	Giger Muller

Chapter one

Introduction

Chapter One

Introduction

1.1 Introduction

Radiation protection, sometimes known as radiological protection, is the protection of people and the environment from the harmful effects of ionizing radiation, which includes both particle radiation and high energy electromagnetic radiation.

Ionizing radiation is widely used in industry and medicine, and it presents a significant health hazard. It is also present as cosmic rays in outer space, so spacecraft and spacesuits must have appropriate shielding. It causes microscopic damages to living tissue, resulting in skin burns and radiation sickness at high exposures, and statistically elevated risks of cancer at low exposures. Radiation protection can be divided into occupational radiation protection, which is the protection of workers, medical radiation protection, which is the protection of patients, and public radiation protection, which is protection of individual members of the public, and of the population as a whole. The types of exposure, as well as government regulations and legal exposure limits are different for each of these groups, so they must be considered separately. As the nature and properties of those ionizing radiations were unknown in the early days, many persons were injured while working with x-ray machines and handling radioactive materials (Max H. Lombardi 2007.)

As soon as radiation injuries were recognized, scientists worked diligently to attain a better understanding of the nature, properties, and interactions of ionizing radiations with living and nonliving matter. Those scientists, working in close cooperation with national and international scientific organizations, have made recommendations for the safety of workers and members of the general public. In each country, those recommendations have been translated into laws and regulations aimed at ensuring the safety of

individuals and populations(Radiation Safety in Nuclear Medicine, Secondedition, Max H. Lombardi).

1.2. About nuclear medicine:

NM is a branch of medicine that use safe, painless and cost effective techniques to image the body (anatomy and physiology) and treat diseases using radioactive materials.In nuclear medicine clinical information is derived from observing the distribution of a pharmaceutical administered to the patient. By incorporating a radionuclide in to the pharmaceutical, this property of radiopharmaceuticals gives 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. Measurements can be made of the distribution of these radiopharmaceuticals by noting the amount of radioactivity present. These measurements may be carried out either in vivo or in vitro.

1.2.1 Diagnostic Nuclear Medicine:

. In diagnostic nuclear medicine a radiopharmaceutical is introduced into the body by injection, ingestion, or inhalation. The radiopharmaceutical is attracted to particular organs, bones, or other tissues. The radioisotope releases small amounts of energy (radiation) that can be detected outside the body by special “cameras.” These cameras record the movement and localization of radiopharmaceuticals in the body. The resulting 2- and 3-dimensional images document the function (metabolic, physiologic, and pathologic) of the tissue or organ of interest.Physicians examine these images to evaluate and diagnose a large number of diseases.

1.2.2 Therapeutic Nuclear Medicine:

In therapeutic nuclear medicine (radionuclide therapy),an amount of a radiopharmaceutical is introduced into the body by injection or ingestion. The radiopharmaceutical is taken up by the specific organ of interest or tissues. From their locations within the body, the radioisotope releases small amounts

of energy (radiation) which will act on cells (target cells) and/or organs (target organs). This irradiation can be for the purpose of a curative treatment (for instance thyroid cancer), palliative treatment (for instance for bone pain) or to reduce an organ's function (for instance an over-active thyroid).

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 sub cellular 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. (Nuclear Medicine technology and technique.)

1.3. Problem of the study:

The inadequate radiation protection awareness and radiation protection plans in nuclear medicine facilities in Sudan is considered to be as a serious issue since it may lead to unjustified radiation exposure. to the best of the researchers knowledge. The radiation dose at the hot lab of nuclear medicine department has variable amount at different distances hence the presence of persons inside the lab at any distance may lead to radiation rick. Sudan was always considered to be as a poor applier country for radiation protection criteria in the medical field due to its poor financial resources.

1.4. Objectives of the study:

1.4.1 General objective:

To evaluate the radiation safety programs applied in nuclear medicine Department of Fedail Specialized Hospital, Sudan (private center).

1.4.2 Specific objectives

- To measure the radiation level in the nuclear medicine hot lab during elution of Tc^{99m} generator, at Fedail Specialized Hospital.

- To assess the dose received by the hands and the whole body of the technologist during the elution process.
- To assess the procedures of receiving radioactive packages applied in the department

1.5 Study Outline:

The study is composed of six chapters: the first chapter is an introduction to the study, the second chapter covers the theoretical background and the literature review associated with the study, chapter three deals with the materials and methods been used in order to achieve the objective of the study, Chapters four represents and discusses the results. Chapter five is about the conclusion and recommendations of the study. In addition to the appendix and references.

Chapter two

Chapter Two

LITERATURE REVIEW

2.1 Theoretical Background:

2.1.1 Introduction

Nuclear medicine is defined as that medical specialty concerned with the use of unsealed sources of radiation in the diagnosis and treatment of disease. Disease usually begins as disordered function the power of nuclear medicine in clinical diagnosis rests with its ability to detect altered function with great sensitivity. For this reason nuclear Medicine has contributed not only to clinical diagnosis but, to a degree unmatched by other imaging methods, to an understanding of disease mechanisms.

2.1.2 Radiation protection

Radiation protection sometimes known as radiological protection is the protection of people and the environment from harmful effect of ionizing radiation.

2.1.2.1 Basic Principles of Radiation Protection:

Radiation protection is based on principles defined by the International Commission on Radiological Protection (ICRP). Three general principles apply to safe radiation practice, namely justification of practice, optimization of protection and individual dose limits. (Max H. Lombardi2010.)

A. Justification of practices:

The decision to perform a nuclear medicine procedure rests upon a Professional judgment of the benefits that accrue to the total health of the Patient, as opposed to any detrimental biological effects that might be caused by the ionizing radiation. The benefit will be the potential diagnostic Information or therapeutic effect of a radionuclide therapy procedure resulting from the medical exposure, including the direct health benefits to an individual as well as the benefits to society.(SIMON.R2003).

B. Optimization of protection and safety:

The benefits must be increased and detriments decreased as far as possible; this is the basis of the ALARA principle, and the UK ALARP principle (but ALARP does not consider social and economic factors and is developed from Case Law)). Radiation protection uses optimization to reduce exposures below Dose Limits.

C-Dose limitation:

All exposures must be kept as low as reasonably achievable and the sum of the doses from all relevant practices must not exceed the doses limits. It is not normally expected that limits should be reached. (Max H. Lombardi2010.)

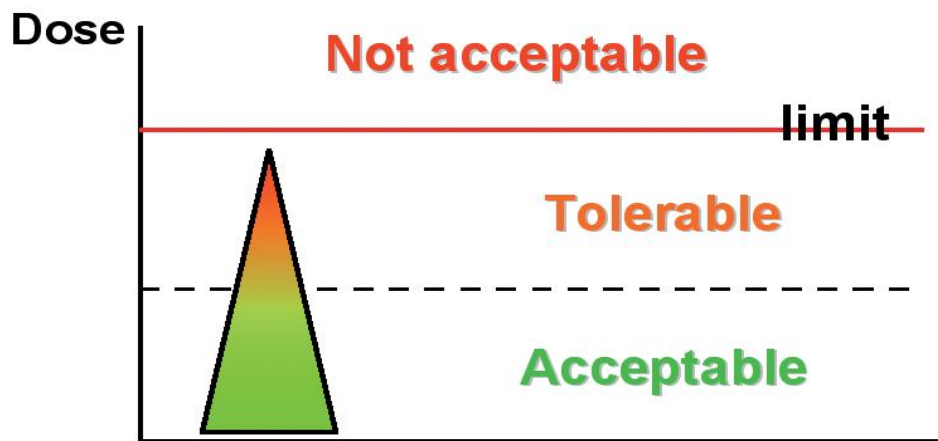


FIGURE (2.1) Principle of limitation of doses

Three types of exposure can be considered:

- **Occupational:** incurred at work;
- **Medical:** incurred by individuals as part of their own medical diagnosis or treatment and exposures incurred knowingly and willingly by individuals helping in the support and comfort of patients undergoing diagnosis or treatment
- **Public:** encompassing all exposures to radiation except occupational and medical ones.

2.1.2.2. Basic measures in Radiation Protection:

Shortening the time of exposure, increasing distance from a radiation source and shielding are the basic countermeasures (or protective measures) to reduce doses from external exposure.

Time: The shorter the time that people are exposed to a radiation source, the lower the absorbed dose.

Distance: The farther away that people are from a radiation source, the lower the absorbed dose.

Shielding: Barriers of lead, concrete or water can stop particle radiation or reduce electromagnetic radiation intensity.

To reduce doses from intake of radioactive substances, the following basic countermeasures can be considered:

1. Shortening time of exposure to contaminants;
2. Preventing surface contamination;
3. Preventing inhalation of radioactive materials in air; and
4. Preventing ingestion of contaminated foodstuffs and drinking water.

2.1.2.3 Basic definitions:

Exposure:

The Exposure may be defined as “the amount of charges generated by ionization electromagnetic radiation per unit mass”

Absorbed dose:

The fundamental dosimetric quantity D, defined as:

$$D = d\varepsilon/dm$$

Where $d\varepsilon$ is the mean energy imparted by ionizing radiation to matter in a volume element and dm is the mass of matter in the volume element.

- The unit for absorbed dose is joule per kilogram (J/kg), given the name gray (Gy).

- The energy can be averaged over any defined volume, the average dose being equal to the total energy imparted in the volume divided by the mass in the volume.

Accident:

Any unintended event, including operating errors, equipment failures and other mishaps, the consequences or potential consequences of which are not negligible from the point of view of protection and safety.(SIMON.R 2003).

Activation:

The process of inducing radioactivity.

Activity:

1. The quantity A for an amount of radionuclide in a given energy state at a given time, defined

as:

$$A_{(T)} = dN/dt$$

Where dN is the expectation value of the number of spontaneous nuclear transformations from *the given energy state in the time interval dt*.

The SI unit of activity is the reciprocal second (s⁻¹), termed the Becquerel (Bq).

Contamination:

Radioactive substances on surfaces or within solids, liquids or gases (including the human body), where its presence is unintended or undesirable or the process giving rise to its presence in such places.

Containment:

Methods or physical structures designed to prevent or control the release and the dispersion of radioactive substances.

Decontamination:

-The complete or partial removal of contamination by a deliberate physical, chemical or biological process.

Radioactive waste:

-For legal and regulatory purposes, material for which no further use is foreseen that contains, or is contaminated with, radionuclides at activity concentrations or activities greater than clearance levels as established by the regulatory body.

Disposal:

-Emplacement of waste in an appropriate facility without the intention of retrieval.

Unsealed source:

-A radioactive source in which the radioactive material is neither permanently sealed in a capsule nor closely bonded and in a solid form.

2.1.3 Biological effect of radiation:

Very soon after the discovery of radiation and radioactivity short- and long-term negative effects of radiation on human tissue were observed. Adverse effects of X-rays were observed by Thomas Edison, William J. Morton, and Nikola Tesla; they independently reported eye irritations from experimentation with X-rays and

Fluorescent substances. These effects were thought to be eye strain, or possibly due to exposure to ultraviolet radiation. Elihu Thomson (an American physicist) deliberately exposed the little finger of his left hand to X-rays for several days, for a short time each day, and observed pain, swelling, stiffness, erythema, and blistering in the finger, which was clearly and immediately Related to the radiation exposure.

2.1.3.1 Stochastic versus Nonstochastic Effects:

There are two broad categories of radiation-related effects in humans, stochastic and nonstochastic.

There are three important characteristics that distinguish them.

-Nonstochastic Effects

Nonstochastic effects (now officially called “deterministic effects,” previously also called “acute Effects”) are effects that are generally observed soon after exposure to radiation. As they are “nonstochastic” in nature, they will always be observed (if the dose threshold is exceeded), and there is generally no doubt that they were caused by the radiation exposure. The major identifying characteristics of nonstochastic Effects are:

1. There is a threshold of dose below which the effects will not be observed.
2. Above this threshold, the magnitude of the effect increases with dose.
3. The effect is clearly associated with the radiation exposure.

Examples include:

- _ Erythema (reddening of the skin)
- _ Epilation (loss of hair)
- _ Depression of bone marrow cell division

-Stochastic Effects

Stochastic effects are effects that are, as the name implies, probabilistic. They may or may not occur in any given exposed individual. These effects generally manifest many years, even decades, after the radiation exposure (and were once called “late effects”). Their major characteristics, in direct contrast with those for nonstochastic effects, are:

1. A threshold may not be observed.
2. The probability of the effect increases with dose.
3. You cannot definitively associate the effect with the radiation exposure.

Examples include:

- _ Cancer induction
- _ Genetic effects (offspring of irradiated individuals)

2.1.3.2. Mechanisms of Radiation Damage to Biological Systems:

Radiation interactions with aqueous systems can be described as occurring in four principal stages:

1. Physical
2. Prechemical
3. Early chemical
4. Late chemical

In the physical stage of water radiolysis, a primary charged particle interacts through elastic and inelastic collisions. Inelastic collisions result in the ionization and excitation of water molecules, leaving behind ionized (H_2O^+) and excited (H_2O^*) molecules, and unbound sub excitation electrons (e_{sub}). A subexcitation electron is one whose energy is not high enough to produce further electronic transitions. By contrast, some electrons produced in the interaction of the primary charged particle with the water molecules may have sufficient energy themselves to produce additional electronic transitions. These electrons may produce secondary track structures (delta rays), beyond that produced by the primary particle. All charged particles can interact with electrons in the water both individually and collectively in the condensed, liquid phase. The initial passage of the particle, with the production of ionized and excited water molecules and sub excited electrons in the local track region (within a few hundred angstroms), occurs within about 10^{-15} s. From this time until about 10^{-12} s, in the prechemical phase, some initial reactions and rearrangements of these species occur. If a water molecule is ionized, this results in the creation of an ionized water molecule and a free electron. The free electron rapidly attracts other water molecules, as the slightly polar molecule has a positive and negative pole, and the positive pole is attracted to the electron. A group of water molecules thus clusters around the electron, and it is known as a "hydrated electron" and is designated as e_{aq} . The water molecule dissociates immediately: $\text{H}_2\text{O} \rightarrow \text{H}_2\text{O}^+ + e_{\text{aq}}$ $\text{H}_2\text{O} + e_{\text{aq}} \rightarrow \text{OH}^- + \text{H}^+$

excitation event, an electron in the molecule is raised to a higher energy level. This electron may simply return to its original state, or the molecule may break up into an H and an OH radical (a radical is a species that has an unpaired electron in one of its orbitals the species is not necessarily charged, but is highly reactive). $H_2O \rightarrow H \cdot + OH \cdot$ The free radical species and the hydrated electron undergo dozens of other reactions with each other and other molecules in the system. Reactions with other

The early chemical phase, extending from $\sim 10^{-12}$ to $\sim 10^{-6}$ s, is the time period within which the species can diffuse and react with each other and with other molecules in solution. By about 10^{-6} s most of the original track structure is lost, and any remaining reactive species are so widely separated that further reactions between individual species are unlikely.

From 10^{-6} s onward, referred to as the late chemical stage, calculation of further product yields can be made by using differential rate-equation systems which assume uniform distribution of the solutes and reactions governed by reaction-rate coefficients. Cells clearly have mechanisms for repairing DNA damage. If damage occurs to a single strand of DNA, it is particularly easy for the cells to repair this damage, as information from the complementary chain may be used to identify the base pairs needed to complete the damaged area. "Double strand breaks" are more difficult to repair, but cellular mechanisms do exist that can affect repair here also.

2.1.3.3 Classes of radiation injury

Radiation injury is damage to tissues caused by exposure to ionizing radiation.

- Large doses of ionizing radiation can cause acute illness by reducing the production of blood cells and damaging the digestive tract.
- A very large dose of ionizing radiation can also damage the heart and blood vessels (cardiovascular system), brain, and skin.

- Radiation injury due to large and very large doses is referred to as a tissue reaction. The dose needed to cause visible tissue injury varies with tissue type.
- Ionizing radiation can increase the risk of cancer.
- Radiation exposure of sperm and egg cells carries little increased risk of genetic defects in offspring.

Doctors remove as much external and internal (material that is inhaled or ingested) radioactive material as possible and treat symptoms and complications of radiation injury

2.1.4 Design of nuclear medicine department

The physical facilities of an NM department must ensure an efficient, safe, and economical operation. The design depends on the patient load and type of operations. In this section, the basic design of an NM department is described. For instructional purposes, we can tour the department from left to right, according to the levels of radioactivity handled in the various sections:

A. COLD AREAS

These are the areas open to the public, clerical employees, and visitors. No radioactivity is handled in these areas. No radioactive packages or sources are brought into this area, and no radioactive patients are asked to wait there. These areas are the waiting room, the reception room, and the clerical offices. They are also referred to as non restricted areas. The exposure level must never exceed (0.5 μ Sv/h) and (1 mSv/y). In other words, exposure rates for public should always be close to background exposure levels (5-6 mSv/year). Although located within a restricted area, the physicians' Offices, the staff lounge, the chief technologist's office, the control room, and the conference room are also areas in which no radioactivity is handled and, in the spirit of ALARA, should also be cold areas.

B. LUKEWARM AREAS

These are areas in which very low levels of radioactivity are handled, usually microcurie (kBq) levels only. Examples are the non imaging procedures room and the gamma counters room (thyroid uptakes, Schilling tests, blood radio assays, wipe/swab-tests).

zsC.Hot areas

From 1 mCi (37 MBq) to 1 Ci (37 GBq) may be handled in shielded containers and enclosures or stored in shielded cabinets in “hot areas.” Examples are the radiopharmacy or “hot lab” and the “decay-in-storage” areas. The radiopharmacy or hot lab is where radiopharmaceuticals are prepared or received in multiple dose vials, quality-assurance tested, and dispensed into individual dosages. The decay-in-storage room is possibly located in a remote area of the hospital. This area is where radioactive waste is allowed to decay to background levels before disposal.

2.1.4.1 DESCRIPTION OF SOME AREAS (Waiting room and reception):

As outpatients (referrals) arrive, they check in with the receptionist. The control room is alerted, and the preparation for the NM procedure starts. The reception and waiting rooms are no restricted areas. Exposure rates do not exceed 2 mrem/h (20Sv/h). Inpatients (hospitalized) are brought to the NM department as scheduled they check in with the receptionist and go to the assigned area

Control room:

The technologist assigned to this area is responsible for the timely scheduling of patients, procedures, and staff assignments. In the event of emergency scans or cancellations, the control room technologist makes adjustments to continue the uninterrupted operation of the department.

D-imaging room:

For most procedures, planar, SPECT, or PET imaging, technologists bring the prescribed doses of RPs in shielded syringes placed inside shielded containers from the hot lab to the assigned imaging rooms, where patients are already positioned on an imaging table and ready. When all preparations are completed, the RP is injected intravenously. The imaging data acquisition can begin immediately. Some patients

Administered by inhalation using a specially designed dispenser. In all imaging rooms, technologists are responsible for the good care of patients, the radiation safety of the patients and the staff, as well as the quality assurance of the imaging instrumentation.

2.1.4.2 Design of nuclear medicine hot lab:

Hot lab is the room where the highest levels of radioactivity are handled. Some of the tasks performed there are (a) reception of generators and RPs, (b) monitoring of all packages containing radioactivities^{3w}, (c) logging of all radioactivities upon arrival.

2.1.4.2.1 Architectural:**- Interior Materials and Finishes Partitions**

Interior partitions should be primarily painted gypsum wallboard on metal studs

Construction Standard 64-1, X-Ray Radiation shielding and Special Control Room Requirements. Construction documents will require written certification by a registered Health Physicist.

-door of hot lab required to be steel security doors that may in some areas need to have proper lead shielding. Refer to (VA Handbook PG-18-14, Room Finishes, Door and Hardware Schedule, for additional information)

2.1.4.2.2 Structural:

General

The size, weight and support requirements for Nuclear Medicine equipment vary greatly. Manufacturer data sheets should be obtained for each type of equipment under consideration. Configure framing systems to accommodate support and serviceability requirements established by the manufacturer.

Shielding

Radiation shielding is often necessary to protect adjacent occupancies. Give proper consideration

To the weight of shielded partitions, doors, ceilings and floors. In some instances,

Structural building materials may provide adequate levels of radiation shielding in specific directions and may not require additional layers of supplemental shielding. Floor depressions

And / or door jamb reinforcement are sometimes necessary.

Floor Trenching

Identify areas where floor trenching and /or floor penetrations are required to receive equipment infrastructure.

Air Quality and Distribution

The distribution of air must be under negative pressure shall have positive air pressure with respect to the adjoining areas. This is to help maintain a reduced dust environment with respect to the electronic equipment. The transferred air should be no more than 150 cfm (71.0 Liters/second) per undercut door.

Care should be taken to position supply air diffusers so as not to create a draft on patients or on operators.

Exhaust System

If any fume hoods are provided, a dedicated exhaust system should be provided for each

Fume hood. Locate the supply air diffusers as far away from the hood sash opening as possible;

And size to eliminate draft conditions and provide proper air flow at the hood.

2.1.4.2.3 Life Safety:

Purpose

The life safety program should be developed to provide a reliable system to protect the building

Occupants, firefighting personnel, building contents, building structure, and building function.

This can be accomplished by limiting the development and spread of a fire emergency to the area of origin and thereby reduce the need for total occupant evacuation. The design aspects of the facility which relate to the fire and life safety include: Structural fire resistance; Building compartmentalization; Fire detection, alarm and suppression; Smoke control and exhaust; Firefighter access and facilities; Emergency power Emergency Egress and Exit Lighting
New hospital construction and renovated areas of existing facilities are required to be fully protected by an automatic fire suppression system. The minimum width of corridors and passageways in Nuclear Medicine areas is 5'-0" in areas used by staff. The minimum width of corridors in areas used by inpatients is 8'-0" Provide handrails on both sides of the corridors in patient areas

.Nurse control areas are permitted to be open to the corridors. Waiting areas are also permitted to be open to the corridors.

Refer to the latest editions of NFPA 101 "Life Safety Code", International Building Code and additional standards published by the National Fire Protection Association (NFPA).

2.1.5 Things that are present in hot lap:

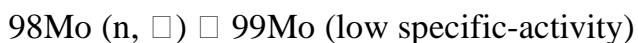
1- The generator which is one of the methods of production of radionuclide used in nuclear medicine. and the other methods of production of radionuclides are briefly described below:

A. Cyclotron Irradiation:

Radionuclides may be made by irradiation of stable atoms with accelerated particles (protons) in a cyclotron. This method of production is especially important for those radioactive atoms used in PET since these usually have very short half-lives and must be manufactured where they are to be used.

C. Reactor Irradiation

Atomic nuclei may be made radioactive by the flux of neutrons in a nuclear reactor or from the fission of heavier atoms. Molybdenum, for example, may be produced by either of the following reactions:



In these reactions n stands for a neutron and γ for a gamma ray. Specific activity is a measure of radioactivity per unit mass of the sample an important factor to consider in the preparation of some radiopharmaceuticals.

Reactor produced atoms are often rich in neutrons and thus decay by β -emissions followed by gamma emission; the energetic electrons give large local radiation doses which may be destructive. This may make them important in therapy as in the use of radioactive iodine to treat Graves' disease and thyroid cancer.

D. Generator Production:

A common strategy in nuclear medicine practice is to take delivery, at a hospital or clinic, of a generator containing a long-lived precursor of a short-lived daughter isotope. The precursor may be made in either a reactor or cyclotron.

Molybdenum-99/technetium-99m generators are very widely used in nuclear medicine, the molybdenum most often being reactor produced. Technetium-99m has many useful features (short half-life, no particulate emissions to cause large radiation doses to patients and a gamma-ray energy ideal for gamma-camera detection) and is more widely used than any other radionuclide at present. Yet with a half-life of about six hours it would not be readily available on the scale on which it is used were it not for its availability from a generator. The generator contains a longer-lived molybdenum-99 parent absorbed onto a column and, as this radionuclide decays, technetium (which being different chemically is not so absorbed) is eluted (milked) from the column in the generator on a daily or twice-daily basis. The molybdenum decays as follows:

$^{99}\text{Mo} \rightarrow ^{99\text{m}}\text{Tc} + \gamma + \beta + \bar{\nu}$ and the technetium used in preparing the radiotracer then decays as follows: $^{99\text{m}}\text{Tc} \rightarrow ^{99}\text{Tc} + \gamma$ with the γ -rays being used for imaging.

2-Radiopharmaceuticals:

-Radiopharmaceuticals are chemical compounds which when administered for a purpose of diagnosis or therapy elicits no physiological response from the patient. The design of these compounds is based solely upon the physiological function of the target organ. Unlike radiographic procedure which depend upon tissue density differences.

3- Dose calibrator:

Is the instrument that used to measure the doses of the patient

4-Contamination monitor It is a device that used to monitor the contamination if it presents it will give alarms sound or light.

5-Survey meter

Universal Survey Meter has the following specifications:

- Dose rate: 0.05 μ Sv/h to 10Sv/h or 5 μ rem/h 1000rem/h
- Dose: 0.01 μ Sv to 10Sv or 1 μ rem to 1000rem

- Manufacture: RADOS Technology OY Finland
- Serial number: 20564389
- Calibration date: 23/2/2012
- Calibration factor: 0.93

Radiation detection:

γ and x rays. For energy 50 Kev to 3Mev, the dose rate from 0.05 $\mu\text{Sv/h}$ to 10mSv/h or 5 $\mu\text{rem/h}$ to 1rem/h and for energy 80 Kev to 3Mev the dose rate from 10mSv/h to 10 Sv/h or 1rem/h to 1000rem/h.



Figure 2.2 show the survey meter RDS-200

6- Contamination monitors:

FHT 111M contamata contamination monitor

- Detectors: Xenon counter tubes with permanent gas filling, windows area 100 or 166 cm^2 .
- Measuring time: Approx. 150 h with batteries at background radiation.
- Manufacture: Thermo Fisher Scientific Inc.
- Units: cps or Bq/cm^2
- Model: FHT 111M

- Display: 0→19.999 B_q/cm^2



Figure 2.3 shows the contamination monitor FHT 111M contamat

MONITOR 4 Contamination monitor

- Manufacture: Made in USA by S.E. INTERNATIONAL, INC.
- Dose rate: 0→50 mR/h or 0→50,000 cpm
- Serial number: 70934



Figure 2.4 shown the contamination monitor MONITOR4

--LB124 SCINT-300 contamination monitor

- Model: LB124SCINT-300
- ID No: 48002BA2

- **Manufacture: BERTHOLD Technologies.**
- **Entrance window's: 150 mm × 230 mm**
- **Sensitive area: 345cm²**
- **Maximum operating time: >50h**
- **Measuring range: 0→50,000 cps.**



Figure 2.5 shows the contamination monitor LB124SCINT-300

3.1.2.4. CoMo 170 contamination monitor

- **Serial Number: 0493CE**
- **Manufacture: NUKLEAR-Medizintechnik Dresden GmbH**
- **Detector size: 170 cm²**
- **Nuclides: 25 nuclides**
- **Dimensions: 280×125×135mm (L, W, H).**
- **Result display: Either in CPS, B_q or B_q/cm²**



Figure 2.6 shows the contamination monitor CoMo 170

- **Dose rate: 0.05μSv/h to 10Sv/h or 5μrem/h 1000rem/h**

2.2: Previous studies:

For many years radiation protection have been subject to various studies and codes of practice guidance documents some of them will be mentioned below:

The study carried out by Taha et al (2008) in which they studied the hand dose in nuclear medicine staff members at National cancer institute Cairo University and The aim of their study is to measure the finger and hand dose during preparation and injection of radiopharmaceutical which is useful in assessment of the extremity dose received by nuclear medicine personnel. Hand radiation dose to occupational workers that handling TC99m labeled compound ¹¹³¹I for diagnostic in NM were measured by thermoluminescence dosimetry. A convenient method is to use TLD ring dosimeter for measuring doses of the diagnostic units of different nuclear medicine facilities Their doses were reported in millisevert that accumulated in 4weeks. The radiation doses to the hands were measured the maximum expected annual dose to extremities appeared to be less than the annual limit(500msv per y) because all of these workers are on rotation and do not constantly handle radioactivity throughout the year.

-WY et al (2002) studied radiation doses to staff of nuclear medicine department and the aim of their study was to measure external radiation doses and estimate internal radiation doses due to the process of radionuclide injection to the staff members working in a nuclear medicine department at queen Mary hospital Hong Kong over a 1year period to assess the possible radiation worker is necessary.

Radiation doses' to 4 nuclear medicine physician, 8 radiographers, and 2 laboratory attendants were measured by digital pocket dosimeter and the result were: the men annual dose for the physician was 0.29mSV) and this was lower than the men annual radiation dose of 2.07mSV to the radiographers and 1.97mSV to the laboratory attendants respectively. The men radiation dose to

the radiographers performing data acquisition and radionuclide injection (1.82) was not different from that of the radiographers performing data acquisition only (2.53). An empirical formula was applied to compute the possible risk of receiving an internal dose to individual staff members performing radionuclide injection was estimated to be 0.01mSV which can be considered negligible in a estimation of total effective dose. This 1 year study showed that effective radiation doses to NM department staff members were within permissible levels and the classification of radiation workers is unlikely to be necessary NM in typical nuclear medicine department in Hong Kong.

- Ali. (2008) RICK, evaluated the radiation received by the staff working in the nuclear medicine department at RICK, results showed that the dose – equivalent rates from bodies and hands of the staff obtained through this work using TLD chips are:

Nuclear medicine technologist body readings was 6.75 mSv per year, physicist body reading 7.89msv per year, chemist body reading 6.1msv per year, and nurse body reading was 8.1msv per year. All the staff readings agree with the national recommendations.

- Bilskaet. al. (2011) Department of Radioisotope Diagnostics, Independent Public Provincial Hospital, Gorzów Wielkopolski, Poland, evaluated the radiation safety at Nuclear Medicine Department being a work environment and analyzed the Ionizing radiation exposure of the employees in the last 19 years, using chest badges The results showed that the Technicians were found to be the largest exposed professional group, whereas nurses received the highest annual doses. Physicians received an average annual dose at the border detection levels. There was no case of an exceeded dose limit for a worker.

Chapter Three

Chapter Three

Materials and methods

3.1 Materials

Different types of dose monitors were used to measure the dose rate and contamination in department under study.

3.1.1/Survey meters:

Survey meter that used to measure the dose rate.

Two types of survey meters were used to measure the dose rates:

3.1.1.1.RDS-120 Survey meter

- Universal Survey Meter, which has the following specifications:
- Dose rate: 0.05 μ Sv/h to 10Sv/h or 5 μ rem/h 1000rem/h.
- Dose: 0.01 μ Sv to 10Sv or 1 μ rem to 1000rem.
- Manufacture: RADOS Technology OY Finland.
- Serial number: 20563054
- Calibration factor: 0.95
- Radiation detection:

γ and x rays for energy 50 Kev to 3Mev, and a dose rate from 0.05 μ Sv/h to 10mSv/h or 5 μ rem/h to 1rem/h. For energy 80 Kev to 3Mev the dose rate from 10mSv/h to 10 Sv/h or 1rem/h to 1000rem/h



Figure 3.1 shown the survey meter RDS-120.:

3.1.2 dose calibrator

Dose calibrator is gas field detector that used to measure the radiation dose.



Fig (3.2) shows the dose calibrator

3.2. Methods

3.2.1 Data collection

The method used to collect the data of this study is:

-On-Field survey: Radiation dose rates were assessed in the department under the study including the background, and the activity of the generator was measured as well.

The reading method performed with the equipment available at the department the dose rate was measured at the fume hood and at 10cm up to one meter distance from the exhaust fan.

3.2.2 Area of the study:

This study was conducted based on original data that were collected from Nuclear Medicine department in Fedail Specialized Hospital (FSH).

3.2.3 Data size:

One dose rate measured at the Radio isotope shield and 9 doses measured at points of 10cm distances from the generator in the hot lab of the department.

3.2.4 Data analysis

The data were performed using computer programs including excel and SPSS.

Chapter Four

Chapter Four

Results

The following chapter will highlight the result related to TC99m generator activity and the dose rate in usv in the hot lab at different points.

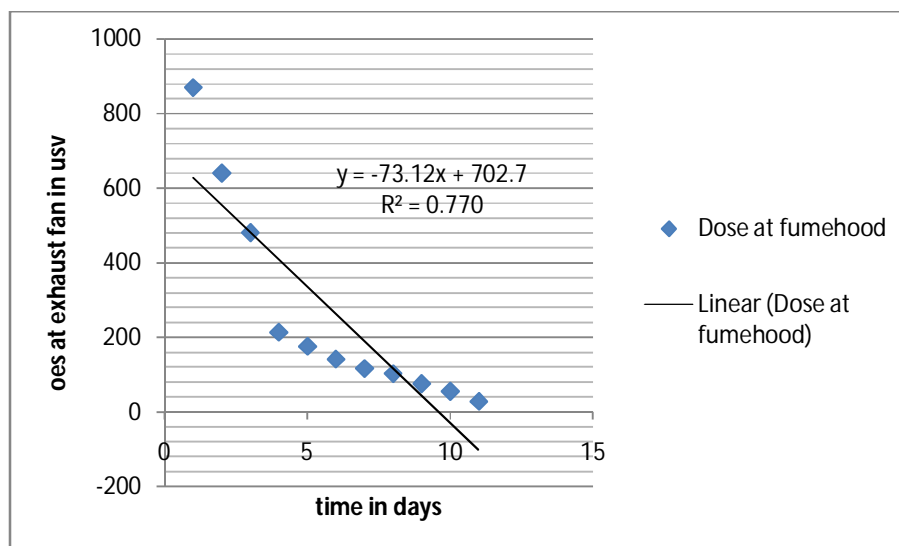


Figure 4.1 shows the dose at fume hood versus time in days.

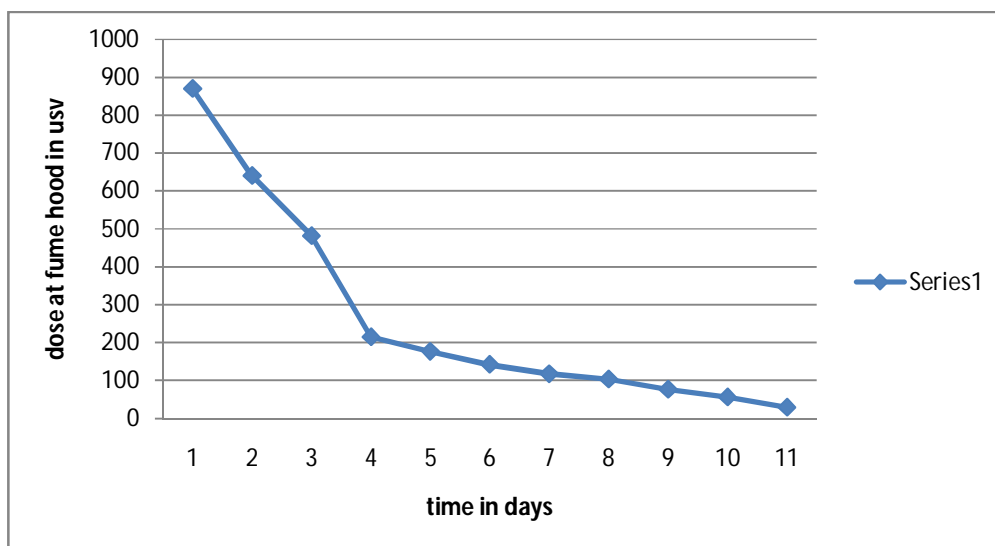


Figure 4.1 shows the dose at exhaust fan versus time in days

Figure 4.2 shows the total activity per day and the dose rate at 50cm from the fume hood.

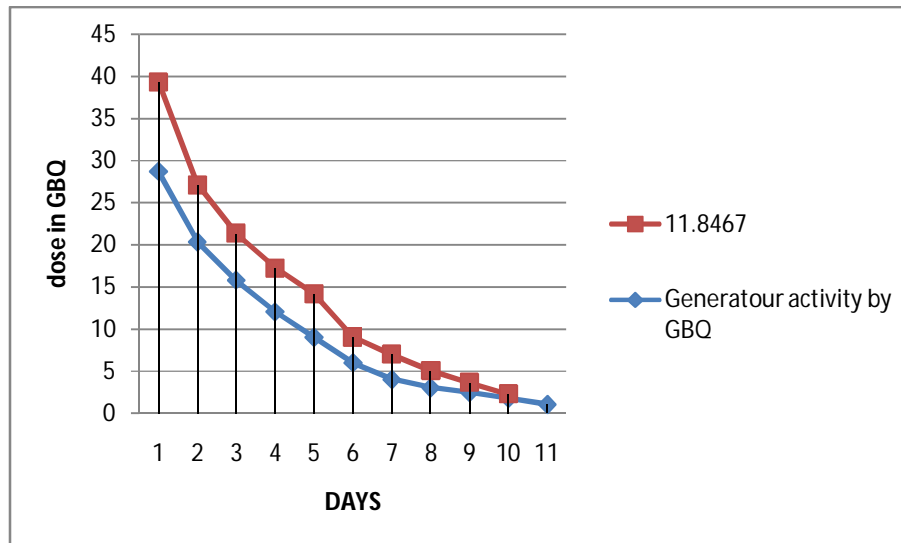


Figure 4.3 shows the total activity per day and the dose rate at 50cm from the fume hood.

Fig4.3 shows the daily received dose by technologist hands in usv during generator elution.

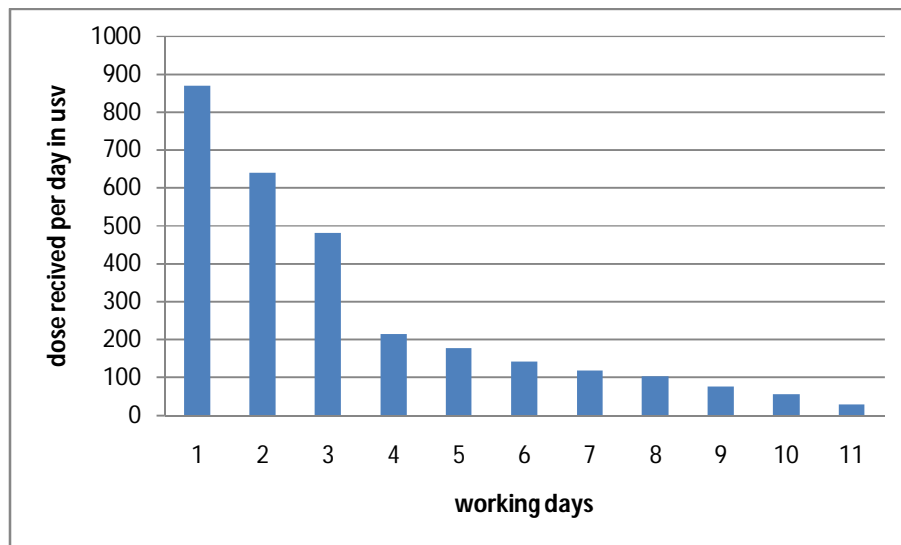


Fig4.4 shows the daily received dose by technologist hands in usv during generator elution

Chapter Five

Chapter Five

Discussion Conclusion and recommendations

5-1 discussion

- The dose decrease following the time passing and the dose at exhaust fan and the time could be correlated in the following equation $Y = -73.126x + 702.71$ where Y refers to the dose at exhaust fan and X to the elapsed time while the decay constant of gamma photons is 0.11.
- On the first day the activity of the TC99m generator was 28.27GBQ which is the highest value and the activity exponentially decreased daily following the fitting equation $Y = 1.107x + 1.9508$ where y refers to activity in GBQ and x refers to time in days.
- The maximum dose received by the technologist body on the first day of elution was 869.9 usv and the second day was 640.4usv then 481.3 usv. However the summation of doses during the total elution period will lead to an exposure dose of 2903.45 usv at point1 which is in the range of permissible dose of the worker and it represent only 3.8% and the whole body dose was 54.9 usv that represented 0.0732% of MPD.
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- In the previous studies there is difference in place of reading and space of hot lab of the department so the readings are not the same..

5.2 conclusion

The main objective of this study was to estimate radiation exposure dose at hot lab of nuclear medicine department at FSH and the mode of generator decay relative to exposure dose inside the fume hood and at hot lab area. Sort of radiation survey was carried out using Geiger Muller audio digital type to detect and measuring the dose at different point at hot lab area. And the study revealed that:

The maximum exposure dose 2.3 msv during elution period (11 days exposure) i.e. hands exposure.

The whole body exposure was 0.066 msv during total period of elution (11 days).

The exposure rate decreases from 2.3 following the distance of inverse square law and the exponential frame as: **$Y = -73.126x+702.71$**

The first day of elution gives about 11.84 usv for the body and the exposure dose decrease following the generator decay proses.

5.2 Recommendations:

- The staff must have a good awareness about the radiation hazards and protection through lectures, training, reading...etc.
- In the hot lab the staff must consider ALARA principle as a very important principle in radiation protection.
- The staff should minimize the time spent inside the hot lab to the shortest possible time to decrease radiation exposure. According to the inverse square law, the staff should be as far as possible from the generator, the use of tongs and forceps increases the distance and the minimizes the dose cleaning of the hot lab must be done professionally by specialized authority have a good awareness about the radiation hazards.
- The radioactive waste must be disposed of in special containers of appropriate thickness rather than the plastic bags which are used in FSH hot lab.
- The staff should make a certain shifts to organize the duties and to minimize the exposure rates.
- for further protection must wear lead glasses to minimize the exposure to the eye lenses should be worn.
- The staff must wear finger ring TLD to estimate the dose to the fingers.
- The authorities should establish radiation protection courses inside and outside the country to raise the awareness about the radiation protection among the staff.
- Future studies on large samples with different methods and at other nuclear medicine departments should be encouraged.

References:

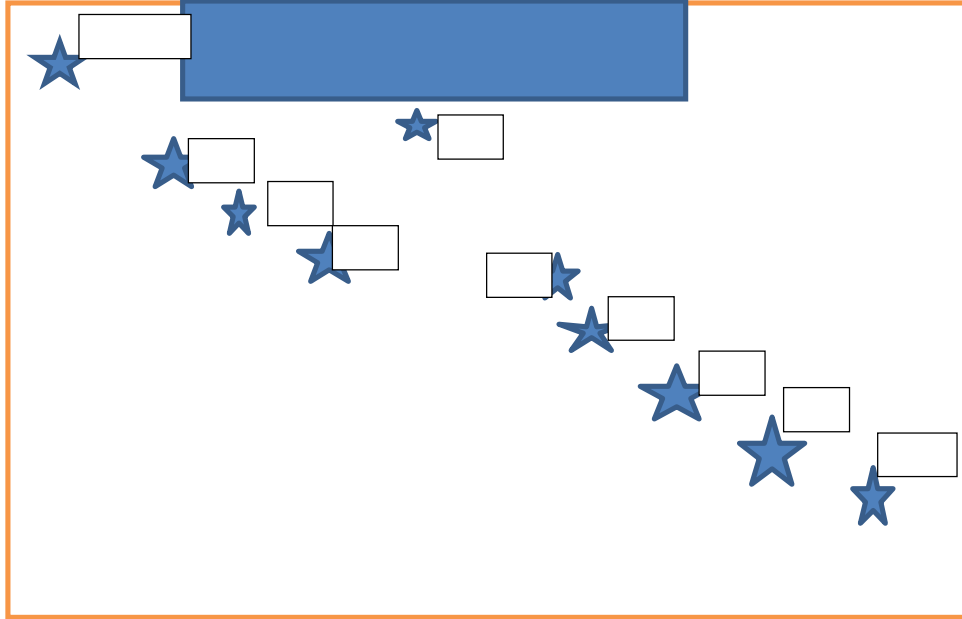
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Appendices

Appendix 1 shows the master table for the daily activity of Tc99m generator and dose measured at different points in usv.

Generatour activity by GBQ	Dose at fumehood	P2	P3	P4	P5	P6	P7	P8	P9	P10
28.72	869.9	17.0062	13.7965	12.9142	11.8467	11.541	10.6872	10	9.8099	9
20.33	640.4	11.2884	11.2885	11.5154	11	11	10.4786	10.3013	9.9614	9.3556
15.8	481.3	7.4847	7.3301	7.0989	6.7915	6.591	5.5154	5.429	5.1105	4.4197
12.04	214.2	6.3804	6.0804	5.4847	5.5614	5.3007	5.1473	4.0614	3.3743	3.2792
9.03	176.07	6.2577	6.0712	5.3804	5.22089	5.14727	4.3742	3.7301	2.3362	2.092
6.01	141.8	5.5215	5.5215	5.2761	5.1534	4.908	4.1166	3.908	2.0804	1.681
4.02	116.8	3.73008	3.69327	3.681	3.0491	2.6626	2.1534	1.9264	1.9202	1.5675
3.03	102.8	3.0675	3.681	3.4356	3.0183	2.681	2.4853	1.0675	0.908	0.5929
2.5	76.14	2.3313	2.2767	2.1767	2.0313	1.6994	1.681	1.045	0.845	0.2086
1.8	55.46	1.8405	1.3313	1.2313	1.1313	1.0724	0.6386	0.5405	0.3453	0.2724
1.05	28.58	1.16565	1.227	0.6135	0.5043	0.421	0.3221	0.2362	0.2313	0.1043
104.33	2903.45	66.07393	62.29747	58.8078	54.90949	53.01217	47.5997	43	36.9225	33

Appendix2 shows the contour of the hot lab in nuclear medicine department including the points of measurements.



Appendix 3 shows a diagram of the Nuclear medicine department of Fedail Specialized Hospital

