بسم الله الرحمن الرحيم

Sudan University of Science and Technology

College of Graduate Studies

Evaluation of Thyroid Uptake of Technetium-99m Using Gamma Camera and Dose Calibrator Methods in the National Cancer Institute - Wad Madani

تقويم إمتصاص الغدة الدرقية للتكنيشيوم ٩٩م باستخدام طريقتي القاما كاميرا وقياس الجرعات بالمعهد القومي للسرطان – ود مدني

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الآيـة

بسم الله الرحمن الرحيم

يقول الله عز وجل:

"وَمَا تَوْفِيقِي إِلَّا بِاللَّهِ عَلَيْهِ تَوَكَّلْتُ وَإِلَيْهِ أُنِيبُ"

{سورة هود ، الآية ٨٨}

Dedication

To my all family

*To my parents (**Tageldin & Seham**)*

*To my brothers (**Mohamed & Yousif**)*

*To my colleagues especially (**Mr. Abdelbagi**)*

To my all friends

To any one that help me in this research

Acknowledgment

First of all, I would like to say Alhamdulillah for giving me the health and strength to finish this research.

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his sincere supervision, advice and guidance from the very early stage of this research as well as giving me extraordinary experiences throughout the work, above all he provided by the encouragement.

would like to express my gratitude to college of medical radiological science members and staff.

I would like to the staff of National Cancer Institute, especially the staff of Nuclear Medicine department for their help and cooperation to achieve my gall.

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Abstract

The main objective of this study was to evaluate the thyroid uptake of technetium-99m using gamma camera and dose calibrator methods in National Cancer Institute. This study included 64 patients (90.6% females and 9.4% male) in the age range between 13 - 81 years, with 43.8% of them in age group 31- 48 years and mean of 37.25±14.58 years. The study was done using two methods for dose calibration, gamma camera planar system with pinhole collimator and dose calibrator at distance of 5cm and 7cm from collimator to patient's neck. The duration of the study was from March 2019 to July 2019.

The study showed that the thyroid uptake values using dose calibrator method were more consistent with radiation protection principles of minimizing the exposure to radiation for staff. The method was also had higher values than those measured with gamma camera due to the scatter radiation in the method of gamma camera. Finally, the study revealed that the correlation between the two methods was given by the R-Square of 0.9937 at 5cm distance and 0.9591 at 7cm distance. According to this coefficient there was no big difference in uptake between the two methods especially at 5cm object-to-pinhole distance, which gave the best result for optimum imaging in ^{99m}Tc-pertechnetate thyroid uptake test due to minimum distance.

المستخلص

كان الهدف من هذه الدراسة هو المقارنة بين قيم امتصاص الغدة الدرقية لعنصر التكنيشيوم٩٩م بقياس الجرعة الاشعاعية للمريض بطريقة جهاز القاما كاميرا و طريقة جهاز قياس الجرعات. اشتملت هذه الدراسة على ٦٤ مريضاً (٩٠,٦% إناث ، ٩,٤% ذكور) في الفئة العمرية من (١٣ – ٨١سنة) ، ونسبة ٤٣,٨% منهم في الفئة العمرية من (٣١ – ٤٨سنة) ومتوسط عمر ١٤,٥٨±٣٧,٢٥ سنة. تمت الدراسة بطريقتين لحساب الجرعة الاشعاعية للمريض ، طريقة جهاز القاما كاميرا (زي النظام السطحي والمحدد ، زي الثقب الدبوسي) وطريقة جهاز قياس الجرعات ، على البعدين ٥سم و ٧سم (من الكاميرا الى عنق المريض). أجريت هذه الدراسة بالمعهد القومي للسرطان في الفترة من مارس ٢٠١٩ – يوليو ٢٠١٩م.

أظهرت الدراسة أن امتصاص الغدة الدرقية بطريقة قياس جرعة المريض بمقياس الجرع تتناسق اكثر مع مبادئ الوقاية من الأشعة في تقليل جرعة التعرض للأشعة بالنسبة للعاملين ، وأظهرت الطريقة ايضاً قيّماً أكبر من القيم المقاسة بطريقة القاما كاميرا في مسافة ال٥سم و ال٧سم نتيجة لتشتت جزء من الاشعة في طريقة القاما كاميرا. وأخيراً أثبت الدراسة أن معامل الارتباط بين الطريقتين قد وجد بقيمة ٠,٩٩٣٧ في مسافة ال٥سم و٠,٩٥٩١ في مسافة ال٧سم (من الكاميرا الى عنق المريض) ، ونسبة لمعامل الارتباط يتضح أنه لا يوجد اختلاف كبير بين الطريقتين خصوصاً في مسافة ال٥سم التي تعطي افضل نتيجة لقياس الجرعة الاشعاعية اثناء تصوير الغدة الدرقية باستخدام عنصر التكنيشيوم ٩٩م نسبة لقصر المسافة بين عنق المريض والكاميرا.

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List of Abbreviations

Abb	*Name*
NCI	*National Cancer Institute*
T4	*Thyroxin*
T3	*Tri iodothyronine*
TBG	*Thyroxine-binding globulin*
TSH	*Thyroid stimulating Hormone*
TRH	*thyrotropin releasing hormone*
DTC	*Differentiated thyroid cancer*
MNG	*Multinodular goiter*
CT	*Computed Tomography*
MRI	*Magnetic Resonance Imaging*
NM	*Nuclear Medicine*
RAIU	*Radioactive Iodine Uptake*
TG	*Thymoglobulin*
TPO	*Thyroid Peroxides*
GD	*Graves' Disease*
MBq	*Mega Becquerel*
T½	*Half-Life*
TU	*Thyroid Uptake*
BG	*Background*
ROI	*Region of Interest*
SPECT	*Single Photon Emission Computer Tomography*

Chapter One

Introduction

Chapter one

Introduction

1.1 Introduction:

Estimation of the thyroid gland volume is generally considering being an important in several pathologic situations such as iodine deficiency, Goiter, thyroiditis, multinodular goiter and others (Zimmermann et al., 2001).

Thyroid scintigraphy and uptake examination is a simple, non-invasive and safe method for evaluation of thyroid gland function and structure. For a standard estimation of thyroid hormonogenesis in clinical practice, radiopharmaceuticals (i.e., ^{131}Iodine, ^{123}Iodine, ^{99m}Technetium) have been commonly quantified for thyroid gland uptake through determining the degree of trapping or organification in the thyroid gland for more than five decades. Use of ^{131}Iodine in thyroid scintigraphy and uptake studies have major disadvantage of high radiation impact on gland (1-3 rad/mCi administered) due to longer half-life and beta particle emission of ^{131}Iodine. ^{123}Iodine has major limitations of high cost and unavailability due to complex production in a cyclotron (SerdarSavaşGül, 2019).

Technetium–99m, in the chemical form of pertechnetate (^{99m}TcO4-), is also used forthyroid scintigraphy and uptake. The similarity of volume and charge between the iodide and pertechnetate ions is the explanation for the uptake of ^{99m}Tc- pertechnetate by the thyroid gland.^{99m}Tc- pertechnetate has been used worldwide to study the thyroid function because of a number of advantages, such as a short half- life (6 hours), short retention in the gland, and no β-radiation, thus providing low dosimetry to the thyroid gland (10,000 times less than that of ^{131}I-iodide), as well as to the body as a whole.10 Its gamma photon of 140 keV is ideal for imaging using scintillation cameras and in addition it has low cost and is readily available. (Celso Darío Ramos, 2002).

Thyroid scintigraphy and uptake studies generally employ a pin-hole or a parallel-hole collimator. It is used together with rotating gamma cameras which have large crystal areas to augment the sensitivity for emission and transmission computed tomography when used with small organs such as the thyroid, brain or heart. For thyroid imaging, scintillation gamma cameras with pin-hole collimator are preferred.

Thyroid gland has low absolute ^{99m}Tc-pertechnetate uptake, which ranges from 0.3 to 3.0% depending upon the method employed. Because of semi quantitative parameters used, higher inter- and intra-observer variability has been reported for ^{99m}Tc-pertechnetate uptake (SerdarSavaşGül, 2019)

1.2 Problem of the study:

The problem of this study lies in the fact that the currently used method for thyroid uptake (full and empty syringes images) generates high radiation dose to the staff, in addition to the possibility of contamination. This should be replaced by dose calibrator method.

1.3 Importance of the study:

This study was a pioneer study in Sudan which a dressed the above mentioned problem, and it could be a base for other studies in the same topic.

The study compared between the gamma camera method and dose calibrator method and find out which of them gives more accurate results.

1.4 Objective of the Study:

1.4.1 General Objective:

To evaluate thyroid uptake using gamma camera and dose calibrator methods.

1.4.2 Specific Objectives

1. To evaluate thyroid uptake with gamma camera method.
2. To evaluate thyroid uptake with dose calibrator method.
3. To compare the results with international thyroid uptake levels.
4. To establish a protocol for accurate calculation of thyroid uptake.
5. To provide additional information about radiation hazard to the staff.

1.7 Research outlines

This study falls into five chapters, Chapter one which is an introduction, it presents the statement of the study problem, importance, objectives and the review of the study. Chapter two contains the background material. Specifically, it discusses the anatomy and physiology as well as pathology of the thyroid gland. This chapter also includes a summary of previous work performed in this filed. Chapter three describes the materials and methods used. Chapter four deals with the results and finally chapter five shows the discussion, conclusion and recommendations and reference list.

Chapter Two

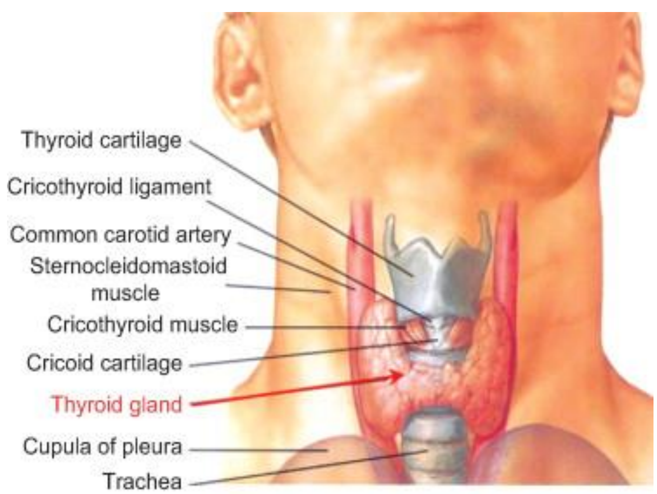
Literature Review& Previous Study

Chapter two

Literature Review& Previous Study

2.1 Anatomy of the thyroid gland:

The thyroid is a bilobed structure evolving from the fourth and fifth branchial pouches. It is initially attached to the ventral floor of the pharynx by the thyroglossal duct. Thyroid tissue may be found anywhere between the base of the tongue and the retrosternal anterior mediastinum. The fetal thyroid gland begins to concentrate iodine and synthesize thyroid hormones by approximately 10.5 weeks, which is pertinent when the administration of 131I to fertile women is contemplated. The two ellipsoid lobes of the adult thyroid are joined by a thin isthmus. Each lobe is approximately 2 cm in thickness and width and averages 4–4.5 cm in length. The thyroid gland, averaging approximately 20 grams in weight, resides in the neck at the level of the cricoid cartilage. A pyramidal lobe is present in approximately 30–50%, arising fromeither the isthmus or the superomedial aspect of either lobe; it undergoes progressive atrophy in adulthood but may be prominent in patients with Graves' disease. Although the right lobe tends to be somewhat larger than the left lobe, there is a great deal of variability in both size and shape of the normal gland (William H. Martin et al., 2005).



Fig(2.1): Anatomy of The Thyroid Gland (Netter, F.H. 1989**)**

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2.1.2 Vascular supply of Thyroid Gland:

The thyroid gland secretes hormones directly into the blood. There for it needs to be highly vascularised. Blood supply to the thyroid gland is achieved by two main arteries; the superior and inferior thyroid arteries. These are paired arteries arising on both the left and right.

The superior thyroid artery is the first branch of the external carotid artery. After arising, the artery descends toward the thyroid gland. As a generalisation, it supplies the superior and anterior portions of the gland.The inferior thyroid artery arises from the thyrocervical trunk (which in turn is a branch of the subclavian artery). The artery travels super medially to reach the inferior pole of the thyroid. It tends to supply the postero-inferior aspect.

Venous drainage is carried out by the superior, middle and inferior thyroid veins, which form a venous plexus. The superior and middle veins drain into the internal jugular veins, whereas the inferior drains into the brachiocephalic vein (TeachMeAnatomy, 2015).

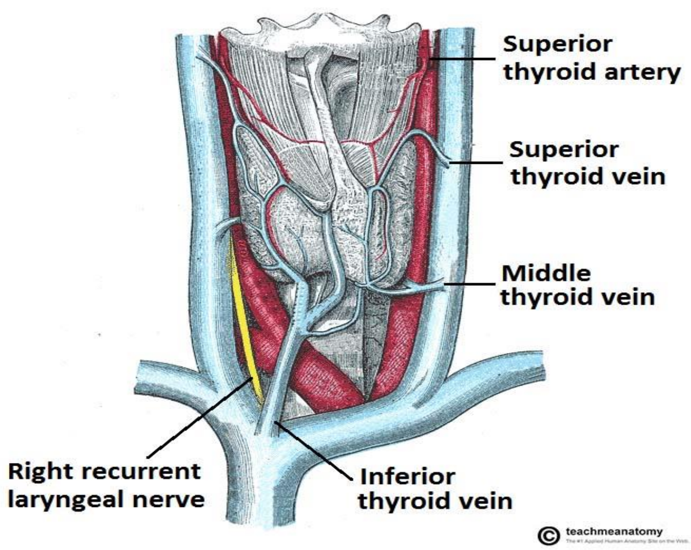

Figure (2.2): Thyroid vascular supply(TechMeAnatomy, 2015)

2.2 Physiology of thyroid gland:

An appreciation of thyroid physiology and pathophysiology is essential for the optimal management of thyroid disorders. The function of the thyroid gland includes the concentration of iodine, synthesis of thyroid hormones, storage of these hormones as part of the thyroglobulin (Tg) molecule in the colloid, and their secretion into the circulation as required. Over 99% of circulating thyroid hormones are bound to plasma proteins, primarily thyroxine-binding globulin (TBG). Only the unbound fraction of thyroid hormoneis metabolically active and, for this reason, accurate assays of free thyroid hormone, “free T4” and “free T3”, have been developed. Dietary sources of iodine include seafood, milk, eggs, and iodized products such as salt and bread. Approximately one-third of the absorbed dietary iodide is trapped by the thyroid, the remainder being excreted in the urine. Although gastric mucosa, salivary glands, and the lactating breast may also trap iodide, none of these organify it. The concentration of iodide by the thyroid gland, synthesis, and release of thyroid hormones are under the regulatory control of the hypothalamic-pituitary thyroid axis. Thyroid stimulating hormone (TSH) from the pituitary plays the major role in regulating thyroid function and this, in turn, is under the control of hypothalamic thyrotropin releasing hormone (TRH) secretion (Stathatos, 2012).

2.3 Pathology of Thyroid Gland:

2.3.1 Goiter:

Any form of thyroid enlargement is called a goiter. The increase in volume is gradual and may be associated with normal thyroid function (euthyroid), decreased function (hypothyroidism) or increased hormonal production (hyperthyroidism). Euthyroid goiter is the most common and iodine deficiency is usually the cause (Cignini et al., 2012).

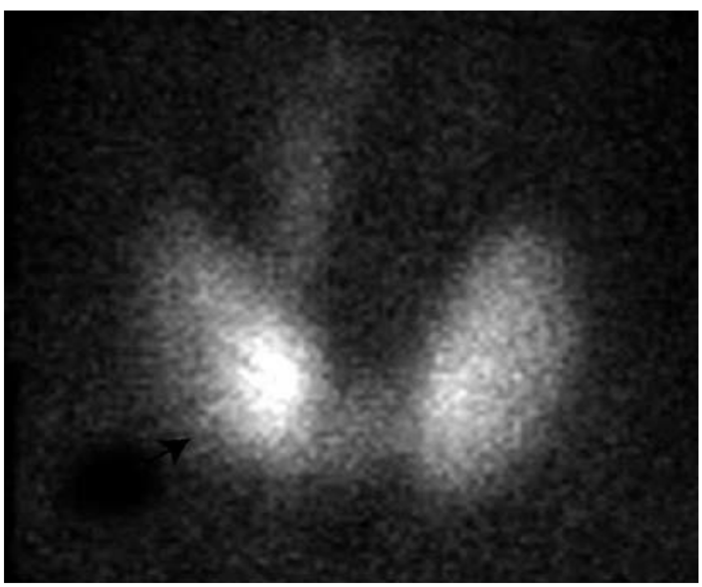

Figure (2-3): 99mTc thyroid scan showsGraves’ disease(Martin P. Sandler et al., 2005).

2.3.2Hyperthyroidism:

Hyperthyroidism is a clinical syndrome of tachycardia, weight loss, and hyper metabolism resulting from supra-physiological circulating levels of thyroid hormones, leading to suppression of TSH secretion. Most cases of hyperthyroidism are due to increased endogenous synthesis and secretion of thyroid hormones from the thyroid. Clinical assessment combined with circulating hormone and thyroid autoantibody measurements, thyroid scintigraphy, and RAIU usually al-low identification of the various disease processes that may be responsible.

Graves' disease (autoimmune diffuse toxic goiter) is due to the presence of thyroid-stimulating immunoglobulins and is associated with autoimmune exophthalmos and pretibial-myxedema. Although it occurs primarily in young women, it may also occur in children and in the elderly. Radioiodine uptake will usually be elevated at 4 hours and/or 24 hours, and the gland will reveal diffuse enlargement in most cases with increased thyroid activity and minimal background and salivary gland activity. Hyperplasia of the pyramidal remnant is seen as increased paramedial activity in as many as 43% of Graves' patients. Occasionally, the gland will appear normal size. The low RAIU (usually ≤5%) of hyperthyroid patients with subacute thyroiditis, postpartum thyroiditis, silent thyroiditis, and surreptitious thyroid hormone administration is easily differentiated from the normal RAIU seen in the occasional patient with Graves' disease. Although ultrasound demonstrates an enlarged homogeneously hypoechoic gland with prominent vascularity on Color-Flow-Doppler imaging ("thyroid inferno"), it is usually unnecessary for diagnosis clinically. The thyroid scan should easily be able to distinguish toxic nodular goiters from Graves' disease. The clinical importance of this is that many patients with toxic nodular goiter will require a higher dose of 131I for therapy than will Graves' disease patients (Martin P. Sandler et al., 2005)

2.3.3 Hypothyroidism:

Hypothyroidism means too little thyroid hormone and is a common problem. In fact, hypothyroidism is often present for a number of years before it is recognized and treated. There are two fairly common causes of hypothyroidism: The first is a result of previous (or currently ongoing) inflammation of the thyroid gland which leaves a large percentage of the cells of the thyroid damaged (or dead) and incapable of producing sufficient hormone. The most common cause of thyroid gland failure is called autoimmune thyroiditis (also called Hashimoto's thyroiditis), a form of thyroid inflammation caused by the patient's own immune system. The second major cause is the broad category of medical treatments. (Milton D. Gross et al., 2005).

2.3.4Thyroiditis

Thyroiditis may be classified as acute, subacute, chronic/autoimmune, and other miscellaneous types; these different types of thyroiditis are unrelated to each other. Acute suppurative thyroiditis is rare and is caused by hematogenousspread of infectious organisms. This is usually defined clinically and evaluated by CT and/or sonography; scintigraphy is only rarely performed. Subacute (de Quervain's) thyroiditis is a benign, self-limited transient inflammatory disease of the thyroid, presumed to be of viral etiology. It may affect the gland diffusely or focally and usually presents as a tender gland in a patient with mild systemic symptoms and an elevated erythrocyte sedimentation rate. Serum thyroglobulin (Tg) is elevated and anti-thyroid antibodies are only marginally increased. A short lived destruction-induced thyrotoxicosis is followed by several months of hypothyroidism, usually subclinical. Thyroid scintigraphy will show poor thyroid visualization with increased backgroundactivity. Most patients are eventually left with a normal thyroid gland, both histologically and functionally. Symptoms respond to non-steroidal or steroidal anti-inflammatory agents and beta blockade (William H. Martin et al., 2005).

A second variety of thyrotoxic subacute thyroiditis is termed silent lymphocytic thyroiditis and is similar in presentation to subacute thyroiditis except for the absence of pain, tenderness, and prodromal systemic symptoms. The etiology is thought to be an exacerbation of underlying autoimmune thyroid disease. Thyroid autoantibodies are present in high titers, but often diminish as the thyrotoxic phase resolves. A destruction-induced hyperthyroidism is accompanied by markedly suppressed RAIU and mild thyromegaly, all of which resolve over months. This entity presents more frequently in postpartum women (termed postpartum thyroiditis) and tends to recur with subsequent pregnancies. Many of these women will eventually develop permanent hypothyroidism (Martin P. Sandler et al., 2005).

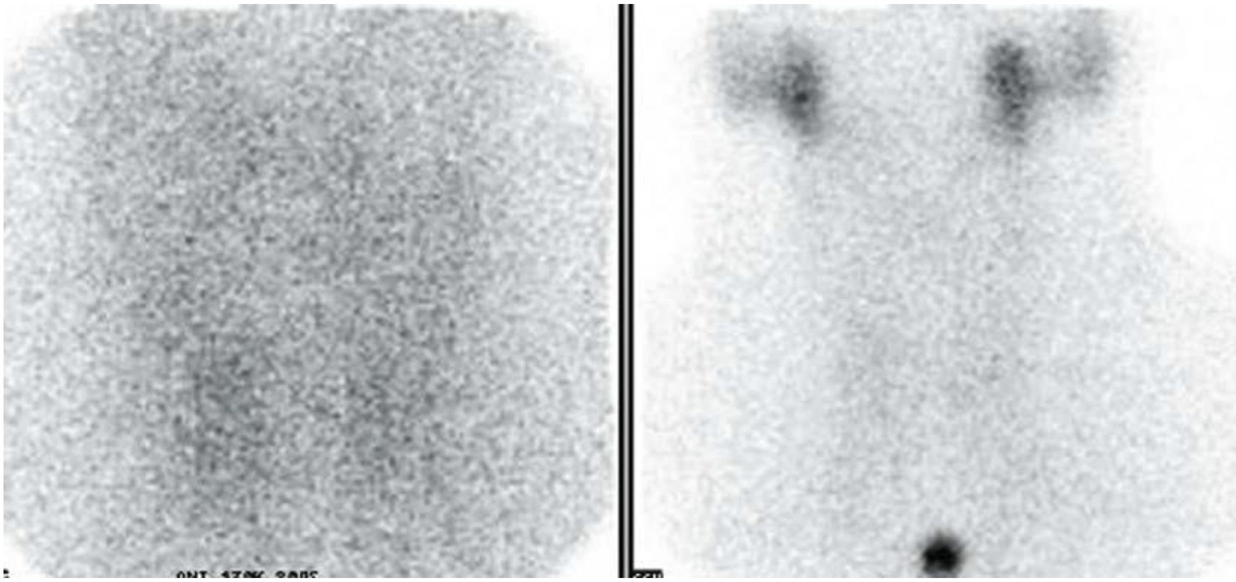

Fig (2-4): An anterior 99mTc image show Subacute thyroiditis(Martin P. Sandler et al., 2005).

2.3.5Thyroid Nodules:

The management of patients with a solitary thyroid nodule remains controversial, related to the high incidence of nodules, the infrequency of thyroid malignancy, and the relatively low morbidity and mortality associated with differentiated thyroid cancer (DTC). Thyroid nodules may contain normal thyroid tissue, benign hypo functioning tissue (solid, cystic, or complex), hyperplastic or autonomously functioning benign tissue, or malignant neoplasm. The evaluation of the patient with a solitary thyroid nodule is directed towards differentiating benign from malignant etiologies. Autopsy series have demonstrated a 50% incidence of single or multiple thyroid nodule(s), only 4% of which are malignant. Ultrasonography detects single or multiple thyroid nodules in 40% of patients with no known thyroid disease. The incidence of thyroid nodules increases with advancing age, and is more frequent in females and in patients with a prior history of neck or facial irradiation (Milton D. Gross et al., 2005).

2.3.6Multinodular Goiter (MNG)

Sometimes hyperplasia and dilatation of follicles with colloid does not affect the thyroid uniformly and results in a multinodular goiter. Thyroid function is usually normal. The patient presents with an enlarged gland and pressure symptoms related to the trachea and esophagus. Multiple cold nodules are demonstrated on NM scans. MNG’s can grow to enormous sizes and are often asymmetrical due to nodule masses of various sizes (Cignini et al., 2012).

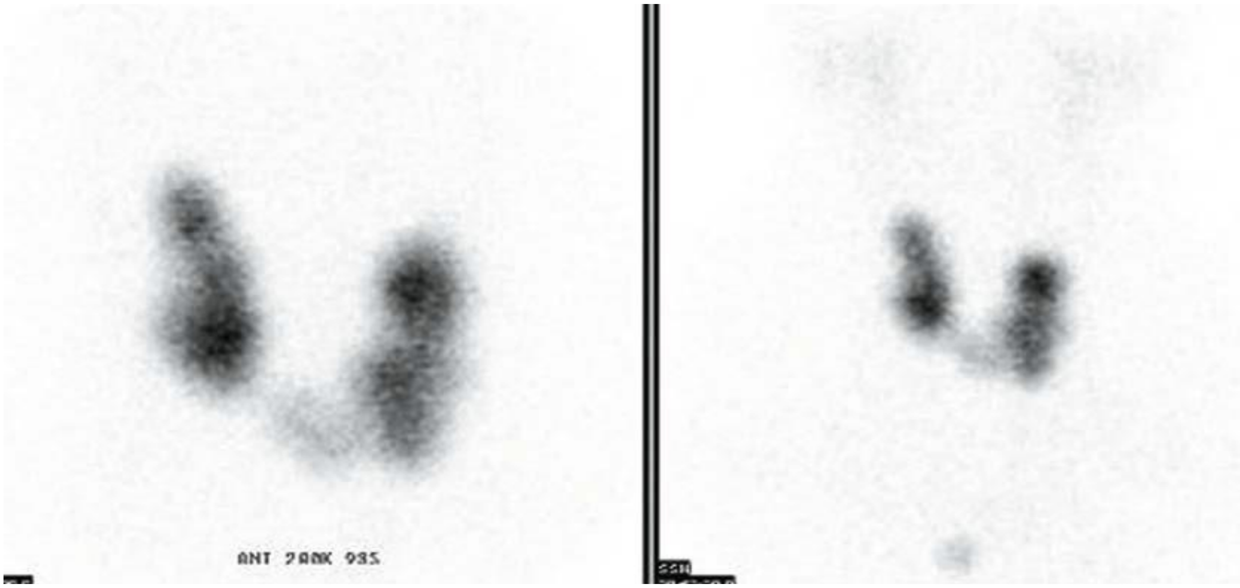

Fig (2-5): Multinodular goiter. An anterior 99mTc pertechnetate view demonstrates asymmetric enlargement of the gland with multiple areas of increased, decreased, and normal activity (Milton D. Gross et al., 2005)

2.4 Nuclear Medicine Imaging:

In nuclear medicine clinical information is derived from observing the distribution of a pharmaceutical administered to the patient. By incorporating a radionuclide into the pharmaceutical, measurements can be made of the distribution of this radiopharmaceutical by noting the amount of radioactivity present. These measurements may be carried out either in vivo or in vitro. In vivo imaging is the most common type of procedure in nuclear medicine, nearly all imaging being carried out with a gamma camera. Nuclear medicine is intrinsically an imaging technique showing the body’s biochemistry, the particular aspect depending upon the choice of the radiopharmaceutical. This is in contrast to other commonly used imaging procedures whose main strengths are showing anatomy. The diagnostic information is provided by the action of the pharmaceutical; the role of the radioactivity is purely a passive one, enabling the radiopharmaceutical to be localized. For this reason, it is possible to use low levels of radioactivity and so the potential hazard to the patient can be kept small (Peter F. Sharp, 2005).

2.4.1 Gamma Camera System:

The gamma camera is the principal instrument for imaging in nuclear medicine and it consists of a large detector in front of which the patient is positioned. Gamma cameras with more than one detector are now common, allowing a higher throughput of patients by acquiring two or more views simultaneously. Every aspect of the modern gamma camera is under computer control, allowing the operator to select the study acquisition time, or the number of counts to be acquired, to set the pulse height analyzers to reject scattered radiation, control the detector and patient bed positions for SPECT and whole body procedures, and display the image. All gamma camera manufactures sell associated computers and software to process and display the acquired images.

The image of the distributionof the gamma-ray-emitting radiopharmaceuticalis produced in the scintillation crystal by a collimator.The gamma rays, which are not visible tothe eye, are converted into flashes of light by thescintillation crystal. This light is, in turn, transformedinto electronic signals by an array of photomultipliertubes (PMT) viewing the rear faceof the crystal. After processing, the outputs fromthe PMTs are converted into three signals, two ofwhich (X and Y) give the spatial location of thescintillation while the third (Z) represents the energy deposited in the crystal by the gamma ray. To improve their quality these signals then pass through correction circuits. The Z signal goes to a pulse height analyzer (PHA), which tests whether the energy of the gamma ray is within the range of values expected for the particular radionuclide being imaged. If the Z signal has an acceptable value, then a signal is sent instructing the display to record that there has been a gamma ray detected, the position being determined by the X and Y signals (Peter F. Sharp, 2005).

Figure (2.6): The gamma camera. The patient is lying between the detectors of this double-headed system. To the right of the camera is a rack containing extra collimators. The technician is seated at the computer controlling data acquisition and image display.

2.4.2 Pinhole collimator:

Pinhole collimators have a single hole that drilled into the sheet with high atomic number material. Lead and tungsten generally used for fabricating the pinhole collimator. This collimator generates magnified images. Smaller pinhole diameter leads to an improvement the spatial resolution, but also a loss in sensitivity. Pinhole collimators are widely used for SPECT imaging of small organ or small region of interest such as the thyroid, the parathyroid glands, the breast, the knee joints and shoulder, or physiological imaging for the small animals. Pinhole collimator is used to obtain a superior spatial resolution compared to conventional parallel-hole collimator Pinhole collimator provides a smaller field of view (FOV) in comparison with a parallel-hole collimator, so these collimators are suited to image the small organs of the body or focal uptake. Small pinhole opening angle makes reduce penetration and short object to collimator distance improve sensitivity and spatial resolution. The sensitivity of a pinhole collimator depends on the inverse square of the distance from the pinhole aperture. It also increases as the square of the pinhole diameter with simultaneous linearly loss in spatial resolution. The magnification factor of a pinhole is determined by the ratio of the pinhole-to-detector distance relative to the pinhole-to-source distance. With increased magnification factor, the detector intrinsic resolution has decreased effect on the total system spatial resolution. Therefore, a pinhole collimator is the most effective for imaging a small object placed close to the pinhole aperture (JalilPirayeshIslamian, 2015)

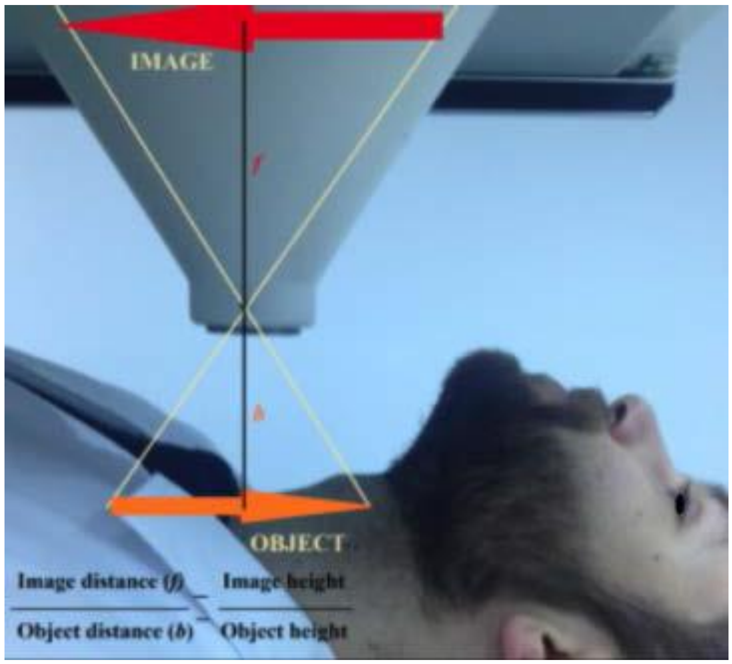

Figure (2.7): Geometry of the pin-hole collimator(JalilPirayeshIslamian, 2015).

2.4.3 Dose calibrator:

A dose calibrator isan integral part of any nuclear medicine department. The typical radioisotope calibrator contains an ionization chamber, a high voltage power supply, an electronic amplifier, and a display unit on which one can select the radioisotope to be calibrated. The ionization chamber is cylindrical in shape and is used to measure the total amount of ionization produced by the sample to be calibrated. The ionization chamber contains Argon gas under high pressure, often 20-30 atmand the hermetically sealed chamber contains two electrodes having an electric potential between them. When the vial or syringe containing the radionuclide is placed into the chamber, the Argon gas is ionized, the ion pairs migrate toward the anode and cathode and an electrical current flows between them. This current is proportional to the activity of the measured radioisotope. The magnitude of this current is usually very small (on the microampere level), even if large amounts of activity are present. A device called an electrometer, designed for quantifying very small electric currents, is used and its output is displayed in either mCi or MBq. Dose calibrator function is based on a number of parameters. Most important are the activity, the energy level of the photons, and whether particulate emitters (e.g., beta particles) are being calibrated. The chamber's response is different for pure gamma emitters like ^{99m}Tc than for a beta/gamma emitter like ^{131}I. This means that the dose calibrator requires a different internal setting for each individual radioisotope (Stephen Karesh, 2016)**.**

Figure (2.8): Dose calibrator (Stephen Karesh, 2016)

2.4.4 Thyroid Scintigraphy:

Thyroid scintigraphy (imaging) can often play an important role in the diagnosis and management of thyroid disease by providing valuable information about thyroid anatomy and function. Nuclear imaging of the thyroid gland provides a pictorial display of functional thyroid tissue following administration of a radioisotope that concentrates in the thyroid tissue.Technetium as pertechnetate (99mTc) and two isotopes of iodine (1231 and 1311) are the radionuclides most commonly used for thyroid imaging.Other radioisotopes of iodine are less suitable because of inappropriate half-lives or photon energies, or an excessive absorbed radiation dose from particulate emissions. Like stable iodine (1271), radioactive iodine is actively concentrated or trapped by the thyroid gland, where it is incorporated into tyrosine residues of thyroglobulin in a process called organification. Pertechnetate ion, with a size and charge similar to that of iodine, is also trapped by the thyroid gland. Uptake of pertechnetate, only reflects the trapping mechanism of the thyroid gland; unlike stable iodine and radioiodine, pertechnetate is neither organically bound to thyroglobulin nor stored in the thyroid gland. Pertechnetate is also trapped to some extent by the salivary glands and gastric mucosa. Disparity between thyroid images obtained using radioiodine and images obtained using pertechnetate, characterized by an increased uptake of pertechnetate, but a decreased uptake of radioiodine, is occasionally observed in human patients with benign and malignant thyroid tumors. Such discordant images result when the thyroid nodule retains the ability to actively concentrate the radionuclide administered but loses the organification function. The choice of isotope depends on several factors, including the purpose of the scan and economic considerations. Although scintigraphy with either radioactive iodine or pertechnetate generally produce comparable thyroid images in both normal and hyperthyroid patients, the technical quality of pertechnetate scans is consistently equal or superior to those obtained with radioiodine.

Pertechnetate has a short half-life (6 hours), emits a low-energy 140 keV photon that is well suited to scintigraphy, and has no beta emissions. Of all of the available radionuclides for thyroid scintigraphy, pertechnetate delivers the lowest radiation-absorbed dose to the thyroid gland. Comparably, 123I has a short half-life (13.3 hours), delivers a low-radiation-absorbed dose since it does not emit beta particles, andemits a 159 keV energy photon well suited for imagingThe major drawback of 123I is that it is considerably more expensive than pertechnetate, which limits its use in veterinary patients. Although 131I is inexpensive and readily available, its long half-life (8.1 days) and the high radiation dose delivered to the patient (resulting from beta particle emission) render it less than ideal for routine scanning. Also, its highenergy gamma photon (364 keV) is inefficiently collimated by the scintillation camera, resulting in relatively inferior images compared with 123I and pertechnetate. Although pertechnetate and 123I have replaced 131I for most thyroid imaging procedures, 131I remains the isotope of choice for the detection of differentiated thyroid metastases in patients with thyroid carcinoma.

Overall, pertechnetate can be considered the radionuclide of choice for routine thyroid imaging for several reasons. Because of the low radiation exposure associated with pertechnetate, higher dosages (measured in mCi) can be safely administered; as a result, thyroid imaging can be completed more rapidly with pertechnetate than with radioiodine. This can be of considerable advantage in veterinary patients, potentially eliminating the need for sedation or anesthesia.

Rapid uptake of pertechnetate by the thyroid gland allows imaging to commence 20 minutes after administration, although later images may be of better qualitybecause of reduced background activity. In contrast, the earliest scanning times for 123I and 1311 are 4 hours and 24 hours, respectively. Finally, administration of antithyroid drugs (e.g., methimazole or propylthiouracil) need not be discontinued before thyroid imaging with pertechnetate because the trapping of pertechnetate by the thyroid gland is not inhibited by these drugs. In contrast, radioiodine may fail to image the thyroid gland during control of hyperthyroidism with antithyroid drugs and these drugs should be discontinued prior to imaging with radioiodine. Overall, pertechnetate is preferred over radioiodine for routine thyroid imaging in veterinary patients for a number of reasons, including more rapid and earlier imaging, lower absorbed radiation dosage, comparable image quality, and economic considerations (Peter P. Kintzer et al., 1994).

Thyroid Scans are used for identifying Nodules and Determining If They Are "Hot" Or "Cold", measuring the size of the goiter prior to treatment, follow-up of thyroid cancer patients after surgery and locating thyroid tissue outside the neck, i.e. base of the tongue or in the chest (Martin P. Sandler et al., 2005)

Tc-99m pertechnetate is injected intravenously into the arm and images of the thyroid are obtained with a scintillation camera approximately 20 minutes later. The radionuclide emits gamma rays (photons) at a predictable rate. The camera is set to detect a predeterminedminimum number of photons. Images are usually obtained from anterior, left anterior oblique and right anterior oblique projections. These phases typically last for several minutes each, with a total scanning time of about 10–20 minutes. The bilobed thyroid gland has reasonably homogenous distribution of activity in both lobes. There is usually slight asymmetry of the lobes (the right being slightly larger), with the lobes joined inferiorly and medially by the isthmus. Two anterior images are usually taken in a study. The first is taken with a sternal notch marker (at a greater stand-off) to check for substernal extension of the thyroid (Joseph C lee MBBS et al., 2012).

Effective doses to staff should not exceed 0.2–0.4 mSv per month even in large departments (Martin P. Sandler et al., 2005)

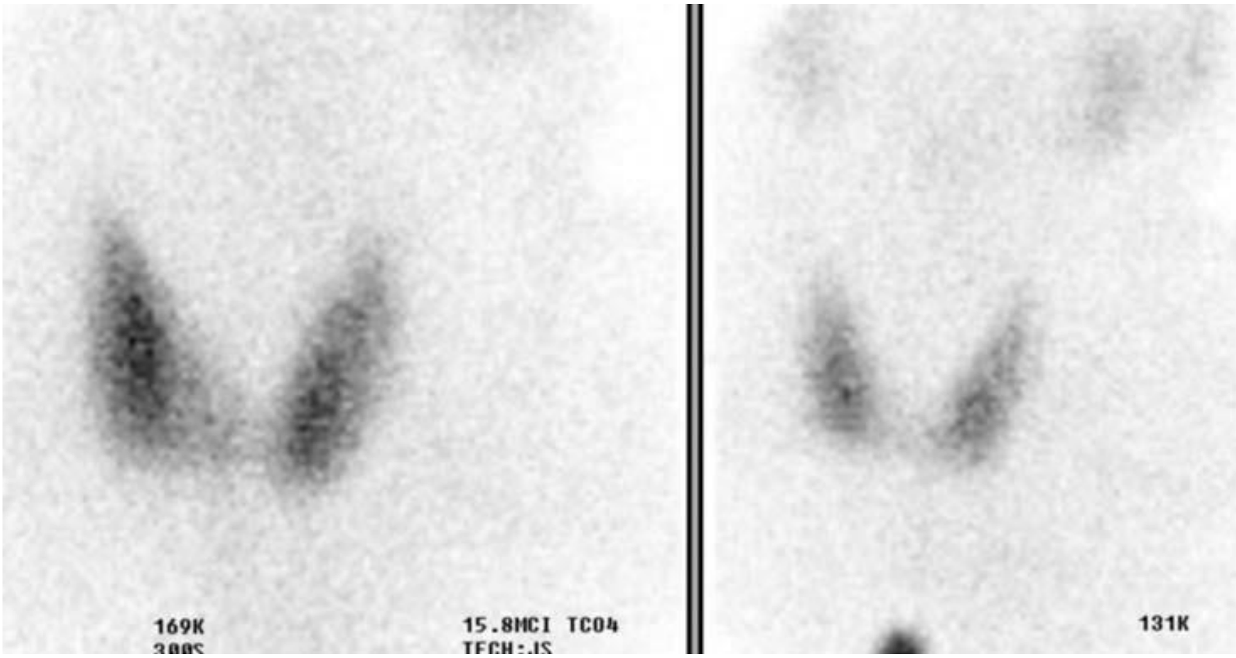

Figure (2.9): Normal 99mTc thyroid scan. Symmetric, homogeneous uptake with less intense salivary gland uptake and only mild background uptake (Martin P. Sandler et al., 2005).

2.5 Previous studies:

- In study done by **(S.L. Bugby, 2014)**in University of Leicester **–** Leicester under title of Characterisation of a high resolution small field of view portable gamma camera**,** used a 3 mm point source with an activity of 21 MBq of ^{99m}Tc positioned 350 mm from the camera face to measure the intrinsic sensitivity. The results show that camera design limits the closest approach to the detector at 10 mm, ∼2860 cps/MBq, at 20 mm is 800 cps/MBq, at 50 mm is 130 cps/MBq, at 100 mm is 30 cps/MBq.

- Other study done by **(Mohamed Abdel-naby, 2012)** in Cairo University, under tittle of Evaluation of Scattered Radiation Effects on the Performance of Gamma Camera, used a specially designed home-made homogenous circular planar flood source filled with 5.3±0.3 mCi of ^{99m}Tcsolution as a scattering medium.Results show apparent increase in the scatter fraction with source thickness, the increase in source thickness is associated with a decrease in the extrinsic sensitivity, this is associated with a decrease in counting efficiency as well. The study also found that the increase in source-to-detector distance, the extrinsic sensitivity decreases, while the counting efficiency increases.

- Radioactive Dose Measurement Based on SPECT Gamma Camera, study done by **(Sulieman M. S. Zobly, 2015)** in Wad Medani - Sudan, used 99mTc, dose calibrator, gamma camera and 3ml syringe. Different numbers of patient doses were considered. The patient dose was measured with the dose calibrator firstly, and then sent to be measured with gamma camera. Each dose measurements in both instruments. The results showed that readings with dose caliber are higher than that with camera but no big difference.

- In study done by **The International Atomic Energy Agency (1989)**in Vienna, under tittle of recommendations for standard uptake measurement, used NaI (TL) detector. The result of the measurement was accurate only when the distance in minimum.

- In study done by **(P. J. HURLEY et al. 1971)** in Canada, under tittle of The Scintillation Camera with Pinhole Collimator in Thyroid Imaging, used both a gamma camera with a pinhole collimator and a rectilinear scanner with an 8-inch crystal. The results show that The average quality of the pinhole images was higher than that of the scans.

- The pattern of thyroid diseases using the nuclear medicine facilities, study done by **Ahmed E. Elmadani et al. (2009)**, in National Cancer Institute – Sudan, useda 5- mm single-hole collimator-equipped gamma scintillation camera 10-20 minutes after intravenous injection of 37-111MBq of sodium pertechnetate ^{99m}Tc. The Female to male ratio is 9:1. The mean age is 34 ±13.36 (1-86 years old) and about 60% of age ranges from 20 to 40 years.

Chapter three

Materials and Methods

Chapter three

Materials and Methods

3.1 Materials

3.1.1 Study type

The study was designed as prospective cross-section studies

3.1.2 Study area

The study was carried, at National Cancer Institute (NCI) – Wad Madani, University of Gezira.

3.1.3 Study duration

The study was carried between March 2019 and July2019**.**

3.1.4 Sample size

The sample of this study were consisted of 64 patients (58 females and 6 male)**,**

3.1.5 Study Population

This study including sixty four patients with normal thyroid uptake.

3.1.6 Equipment used for data collection

The material used to collect the data were categorized into, nuclear medicine an instrument which is MEDISO Planar Gamma Camera, 1995. a low energy, pin-hole collimator was used, window: 20% and the radionuclide ^{99m}Tc injected intravenously, dose: 1-4 mci /37-148 MBq (depending on body weight).

3.2 Methods

3.2.1 Data Collection

The data were collected by using a questionnaire which was designed to include all the needed information, references, and internet.

3.2.2 Technique used in this study:

The patient was prepared according to the following points: patient should stop thyroid medication; stop taking any food contain iodine. If the patient is female, will be inspected if she is pregnancy, the patient will return to their physicians. In case of breast feeding, the patient will be asked to stop feeding for a while until the radioactive substance been execrated from the body (with minimize the injected dose). The history of the patient should be taking into account, and the clinical condition should be noted. The related study must be available, which is help full in diagnosis.

First of all, the extrinsic sensitivity of planar gamma camera was calibrated. known activity and time of a ^{99m}Tc point source in a syringe was measured in the dose calibrator, the point source was carefully aligned with the center of the camera, a static image was obtained at 5cm and 7cm distance between source and pinhole collimator with static parameters (265 x 265 matrix). After that the personal computer program determined the amount of counts\s in one MBq. The results were used in the dose calibrator processing method.

Before the injection of the radioactive dose was measured accurately in the dose calibrator. The dose was minimizing in case of children or low weight patient using different calculation methods, (it is also can be used to maximize the dose in case of high weight patients).Thyroid uptake was performed 15-20 minutes after an intravenous injection of 40-130 MBq (1-3.5mCi) of ^{99m}Tc-pertechnetate for thyroid scan (for maximum concentration of pertchnetate). The calculation of full and empty syringes, before and after radiopharmaceutical injectionwas done by two calibration methods:

1. with dose calibrator measuring in (MBq).
2. with gamma camera images of the full and empty syringe for 1 min (counts).

A planar gamma camera was equipped with a low-energy, general purpose, pin-hole collimator. Images obtain on a 265 x 265 matrix. Patient in supine position with pillow under the shoulder and chin hyper extended for good visualizations of thyroid gland and camera over neck, then 150,000 counts anterior image was obtained this image is used in calculation of thyroid uptake.

(marker with point source ^{99m}Tc was used in the supra-sternal notch (S.S.N) to determine the extension of the gland).

The calculation of thyroid uptake was done by two methods; 1) based on images of the syringe counts before and after radiopharmaceutical injection, 2) based on dose calibrator with the camera sensitivity that was calibrated in the advance. An automatic or manual region of interest (ROI) drew around the borders of the thyroid gland in both methods, and background subtraction was done.

The procedure of the thyroid uptake in one method was calculated automatically by introducing the data of syringes before & after injection using dose calibrator (in MBq), and image of full and empty syringe was done in the other method (All counts were corrected for the acquisition time and decay of technetium-99m.).Then the computer program was automatically measure the actual activity injected to the patient by subtracted the empty activity from the full (MBq\counts), after that the thyroid uptake was measured using special nuclear medicine programaccording to theformula: Thyroid Uptake (%): “T-BG/F-E”. Where (F) is full syringe, (E) is empty injector, (T) is anteriorneck region thyroid and (BG) is background activity values.

3.2.3 Data analysis

After data collection, the data sheet was coded, classified and analyzed byStatistical Package for Social Science software version 16 (SPSS),and personal computer (COMPAQ) version 5722AP\1998.

3.2.4 Data presentation:

The data was presented as complex tables that was used in the analysis, the frequencies were calculated and was carried out the relationship between different variables and the important statistical indicators were drawn from the study.

3.2.5 Study Variable:

The study population assessed against the following variables:

Patients gender, age, full syringe, empty syringe, thyroid uptake at 5cm distance with dose calibrator, thyroid uptake at 5cm distance with gamma camera, thyroid uptake at 7cm distance with dose calibrator, thyroid uptake at 7cm distance with gamma camera, camera sensitivity at 5cm distance and camera sensitivity at 7cm distance.

Chapter Four
Results

Chapter Four

Results

Table (4-1): Shows Frequency distribution of gender.

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	6	9.4	9.4	9.4
Female	58	90.6	90.6	100.0
Total	64	100.0	100.0	

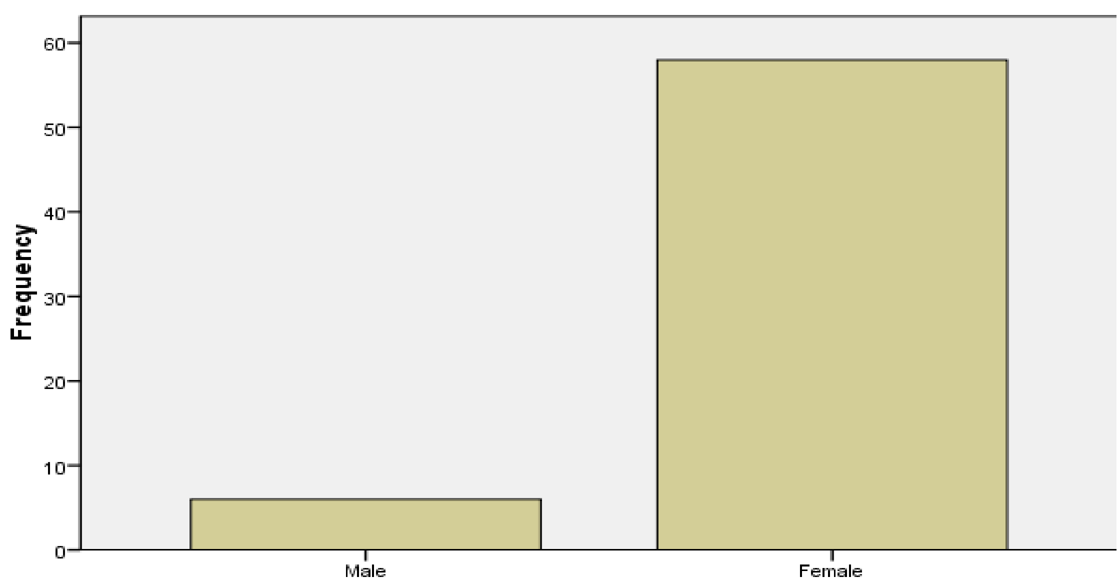

Fig (4-1): Shows Frequency distribution of gender

Table (4-2): Shows Frequency distribution of age group.

Age Group	Frequency	Percent	Valid Percent	Cumulative Percent
13-30 years	25	39.1	39.1	39.1
31-48 years	28	43.8	43.8	82.8
49- 66 years	8	12.5	12.5	95.3
67-81 years	3	4.7	4.7	100.0
Total	64	100.0	100.0	

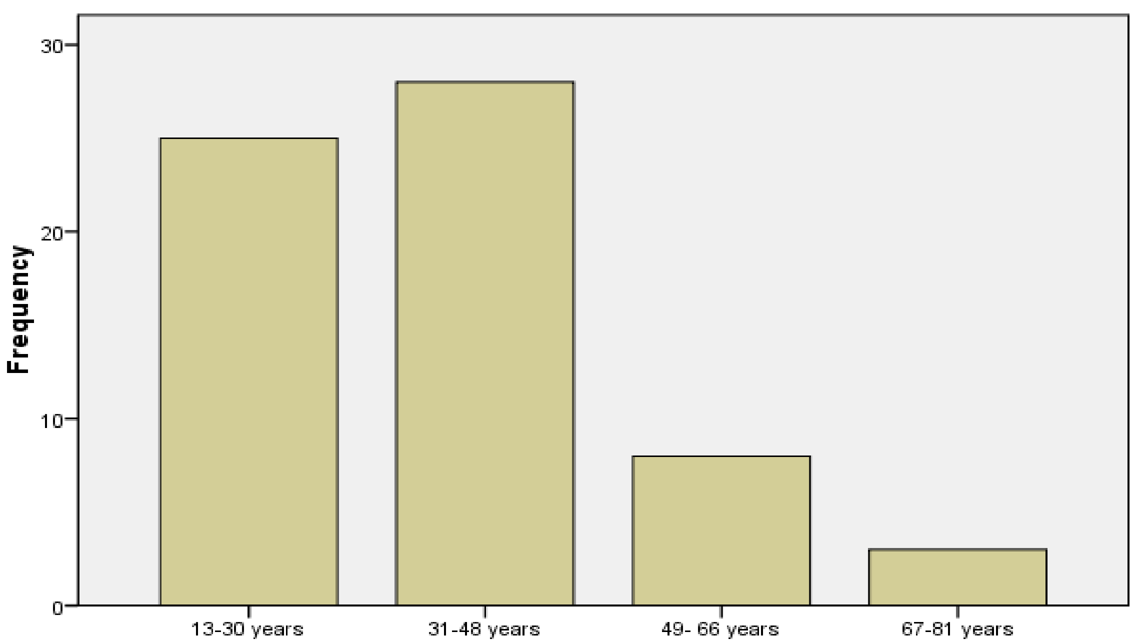

Fig (4-2): Shows Frequency distribution of age group

Table (4-3): shows the sensitivity of planner gamma camera at 5cm and 7cm distance.

Distance	Sensitivity
5cm distance	160 Cps
7cm distance	109 Cps

Table (4-4): Showsthe Minimum, Maximum, Mean and Stander Deviation of age, Dose Calibrator at 5cm & 7cm, Gamma Camera at 5cm & 7cm, Full &Empty Syringe

Characteristics	N	Minimum	Maximum	Mean	Std. Deviation
Age	64	13.00	81.00	37.25	14.58
Dose Calibrator at 5cm	64	0.32	3.44	1.67	0.86
Dose Calibrator at 7cm	64	0.42	4.00	1.95	0.98
Gamma Camera at 5cm	64	0.30	3.38	1.57	0.83
Gamma Camera at 7cm	64	0.40	3.72	1.78	0.90
Full Syringe	64	40.00	130.00	83.25	18.70
Empty Syringe	64	2.00	14.00	6.53	3.13

Table (4-5): Compare mean of Dose Calibrator at 5cm & 7cm and Gamma Camera at 5cm & 7cm in males and females.

A: Compare mean

Group Statistics					
Characteristics	Sex	N	Mean	Std. Deviation	Std. Error Mean
Dose Calibrator at 5cm	Male	6	1.77	1.22	0.50
	Female	58	1.66	0.83	0.10
Dose Calibrator at 7cm	Male	6	2.03	1.40	0.57
	Female	58	1.94	0.94	0.12
Gamma Camera at 5cm	Male	6	1.61	1.16	0.47
	Female	58	1.57	0.81	0.10
Gamma Camera at 7cm	Male	6	1.88	1.32	0.53
	Female	58	1.77	0.86	0.11

Table (4-5) B: Shows the Levine's test in adults (independent sample t- test).

	t-test for Equality of Means						
Characteristic	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						Lower	Upper
Dose5cm	0.28	62	0.78	0.10	0.37	-0.64	0.85
	0.20	5.48	0.84	0.10	0.51	-1.18	1.38
Dose7cm	0.21	62	0.83	0.08	0.42	-0.75	0.93
	0.15	5.47	0.88	0.08	0.58	-1.37	1.55
Camera5cm	0.11	62	0.91	0.03	0.36	-0.68	0.76
	0.08	5.51	0.93	0.03	0.48	-1.17	1.25
Camera7cm	0.26	62	0.79	0.10	0.39	-0.68	0.88
	0.18	5.45	0.86	0.10	0.55	-1.28	1.48

Table (4-6): Compare mean of the Dose Calibrator at 5cm & 7cm and Gamma Camera at 5cm & 7cm in different gender (one ways-A nova).

Gender		Dose Calibrator at 5cm	Dose Calibrator at 7cm	Gamma Camera at 5cm	Gamma Camera at 7cm
Male	Mean	1.77	2.03	1.61	1.88
	N	6	6	6	6
	Std. Deviation	1.22	1.40	1.16	1.32
Female	Mean	1.6684	1.94	1.57	1.77
	N	58	58	58	58
	Std. Deviation	0.83	0.94	0.81	0.86
Total	Mean	1.67	1.95	1.57	1.78
	N	64	64	64	64
	Std. Deviation	0.86	0.98	0.83	0.90
P. value		0.78	0.83	0.91	0.79

Table (4-7): Compare mean of the Dose Calibrator at 5cm & 7cm and Gamma Camera at 5cm & 7cm in different age group (one ways-A nova).

Age Group/ Years		Dose Calibrator at 5cm	Dose Calibrator at 7cm	Gamma Camera at 5cm	Gamma Camera at 7cm	Total Thyroid Uptake
13-30 years	Mean	1.98	2.26	1.88	2.04	2.04
	N	25	25	25	25	
	Std. Deviation	0.82	0.94	0.80	0.86	0.86
31-48 years	Mean	1.36	1.64	1.29	1.52	1.45
	N	28	28	28	28	
	Std. Deviation	0.72	0.86	0.73	0.82	0.78
49- 66 years	Mean	1.94	2.19	1.75	2.00	1.97
	N	8	8	8	8	
	Std. Deviation	0.84	0.85	0.78	0.79	0.82
67-81 years	Mean	1.30	1.61	1.18	1.50	1.40
	N	3	3	3	3	
	Std. Deviation	1.65	2.04	1.48	1.88	1.76

Table (4-8): Shows the correlation between theDose Calibrator and gamma camera at 5cm & 7cm.

	Dose caliber and camera at 5cm	Dose caliber and camera at 7cm
Correlation Coefficient	0.9937	0.9591

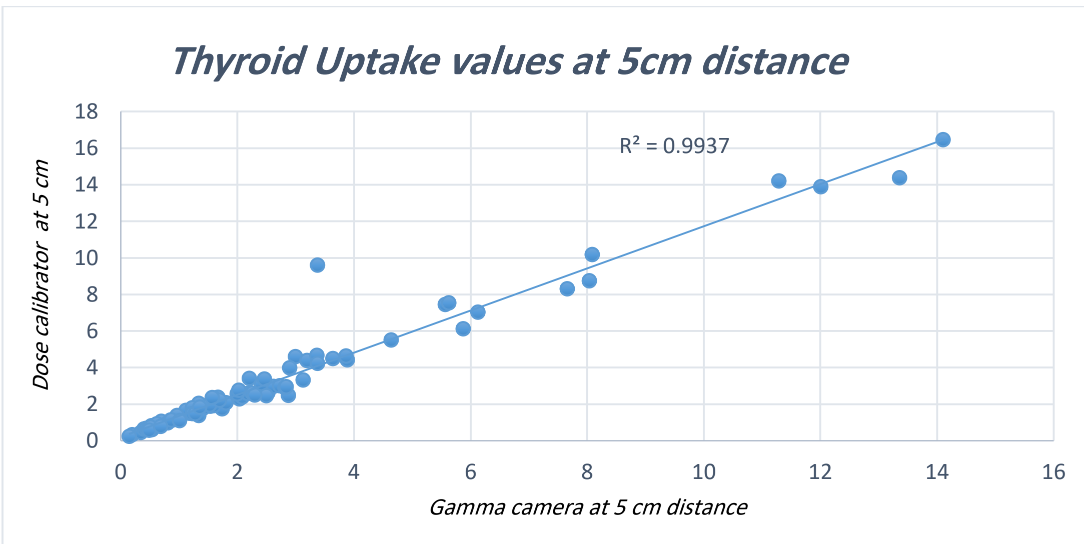

Fig (4-3): shows the correlation between Thyroid Uptake with syringe measured by dose calibrator and gamma camera at 5cm distance.

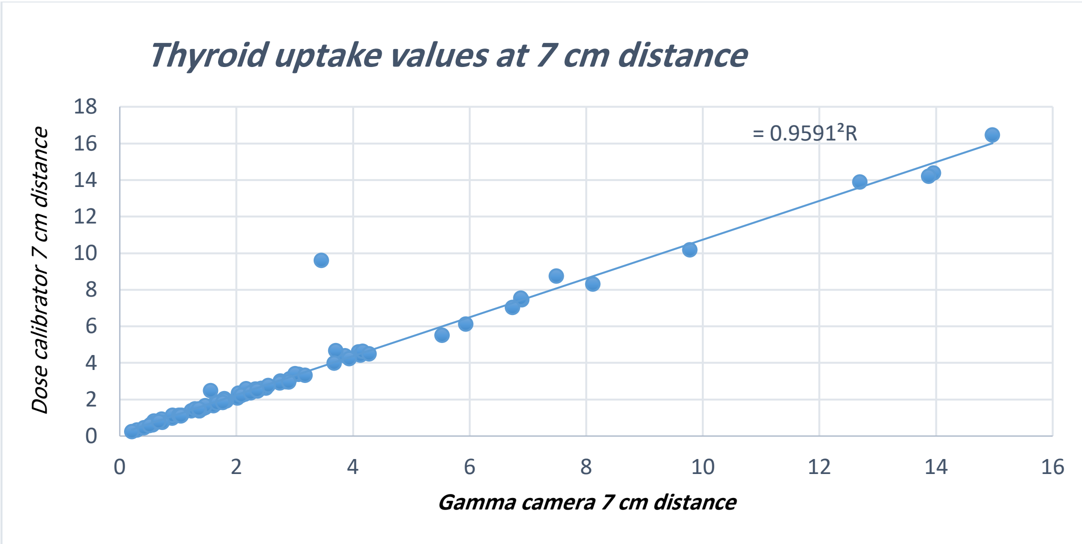

Fig (4-4): shows the correlation between Thyroid Uptake with syringe measured by dose calibrator and gamma camera at 7cm distance.

Chapter Five

Discussion, Conclusion and Recommendations

Chapter Five

Discussion, Conclusion and Recommendations

5.1 Discussion:

This was across sectional study carried out in Wad Medani state in the period from March 2019 and July 2019 aimed to evaluate the thyroid uptake using gamma camera and dose calibrator methods. The study was done in 64 patients.

Study revealed that (58 females represent 90.6% and 6 males represent 9.4%) the high incidence of thyroid problems among female is always expected due to hormones disturbance in females rather than males (John Peter, 1996)Also this result is in agreement with study done by (Ahmed E. Elmadani et al. 2009). Table (4-1)

Concerning the age most patients were inage group 31- 48 years (43.8%) followed by (39.1%) in age group 13- 30 years. The mean age was 37.25±14.58. This result is also agreement with study done by (Ahmed E. Elmadani et al. 2009). Table (4-2)

The study found that the sensitivity of planar gamma camera with source at 5cm was (160 Cps) and at 7cm distance (109 Cps) , as shown that the increasing in source to detector distance is decreasing the sensitivity and this result is in agreement with the study done by (S.L. Bugby, 2014). Table (4-3)

The study found that the minimum, maximum and mean of age was (13.00, 81.00 and 37.25±14.58 respectively). The minimum, maximum and mean thyroid uptake values with dose calibrator at 5cm distance was (0.32, 3.44, 1.67±0.86 respectively). The minimum, maximum and mean thyroid uptake values with dose calibrator at 7cm distance was (0.42, 4.00, 1.95±0.98 respectively). The minimum, maximum and mean thyroid uptake values with gamma camera at 5cm distance was (0.30, 3.38, 1.57±0.83 respectively). The minimum, maximum and mean thyroid uptake values with gamma camera at 7cm distance was (0.40, 3.72, 1.78±0.90 respectively). Themaximum patient dose was 130Mbq and minimum dose was 40Mbq with mean of 83.25±18.70Mbq. The maximum empty syringe was 14Mbq and minimum empty syringe was 2Mbq with mean of 6.53±3.13Mbq. Table (4-4)

The independent sample t-test for comparative of mean thyroid uptake in males and females with dose calibrator at 5cm distance was (1.77±1.22, 1.66±0.83) respectively. And with dose calibrator at 7cm distance was (2.03±1.40, 1.94±0.94) respectively. Then the uptake with gamma camera at 5cm distance was (1.61±1.16, 1.57±0.81) respectively. And with gamma camera at 7cm distance was (1.88±1.32, 1.77±0.86) respectively. As shown that the thyroid uptake was high in male than female. Table (4-5A)

Concerning the independent sample t-test revealed that there was no significant difference between thyroid uptake with dose calibrator and gamma camera for both male and female (P value > 0.05) by 95% confidence interval of difference. Table (4-5B)

The total mean of thyroid uptake values with both dose calibrator and gamma camera at 5cm distance was (1.67±0.86 and 1.57±0.83). And the total mean of thyroid uptake values with both dose calibrator and gamma camera at 7cm distance was (1.95±0.98 and 1.78±0.90) respectively. These results showed that the thyroid uptake values with syringes measured by dose calibrator were higher than those measured with gamma camera. Other study done by Sulieman M. S. Zobly and Abdelbagi O. Osman, 2015 agree with my results. Table (4-6)

The total mean of thyroid uptake in age group 13-30 years was (2.04±0.86), in 31-48 years was (1.45±0.78), in 49-66 years was (1.97±0.82), and in 67-81 years was (1.40±1.76). these results revealed that the thyroid uptake show tendency of decrease at first 1.7 decades then tendency of increase at second 1.7 decades. Table (5-7)

The relationship between thyroid uptake with syringe measured by dose calibrator and gamma camera at 5cm & 7cm distance given a correlation coefficient of 0.9937 and 0.9591 respectively. as shown there is no big change in the uptake at 5cm object-to-pinhole distance which is more accurate due to the minimum distance, this result is agreed with the study done by (IAEA,1989). Table (5-8)

5.2 Conclusion

Uptake of thyroid gland is usually affected by the sensitivity of gamma camera and dose calibrator. This study includes 64 patients(90.6% female, 9.4% male), with 43.8% of patients in age group 31- 48 years and mean of 37.25±14.58 years.The maximum dose of ^{99m}Tc- Pertechnetate given to patient was 130Mbq and minimum dose was 40Mbq according to weight, with mean of 83.25±18.70Mbq,the thyroid uptake values was high in male than in female.

The thyroid uptake valueswith syringes measured by dose calibrator method were higher than those measured with gamma camera, and hence more accurate due to radiation scatter in gamma camera, and the method was also consistent with radiation protection principles of minimizing the exposure to radiation for staff.The correlation between the two methods was given by the R-Square of 0.9937 at 5cm distance and 0.9591 at 7cm distance. According to this coefficient there was no big change in the uptake between the two methods especially at 5cm object-to-pinhole distance, where it gave the best result for optimum imaging in 99mTc-pertechnetate thyroid uptake test.

5-3 Recommendations:

This study would like to highlight some points in a form of recommendations as follows:

- The pinhole collimator is the most suitable collimator for thyroid scan and uptake.
- The pinhole detector should be as close as possible to the patient neck for good sensitivity.
- The dose of ^{99m}Tc must be accurately adjusted using Q.C passed dose calibrator with constant factor for radioactive decay.
- To minimize the radiation exposure dose to the staff and prevent any contamination, the use of dose calibrator method is highly recommended as it is more simple and it takes short time in thyroid uptake.
- The sensitivity of planar gamma camera should be checked every year.
- Changes in the room temperature can affect the scintillation camera's crystal sensitivity, so that an automatic temperature control system should be install in the rooms where the scintillation camera is used.
- The distance between the patient head and gamma camera detector must be constant.
- The time between patient injection and imaging should be constant in15 or 20 min for all subjects.
- Factors like children, breast feeding women and obese patients should be considered when determining the injected dose.

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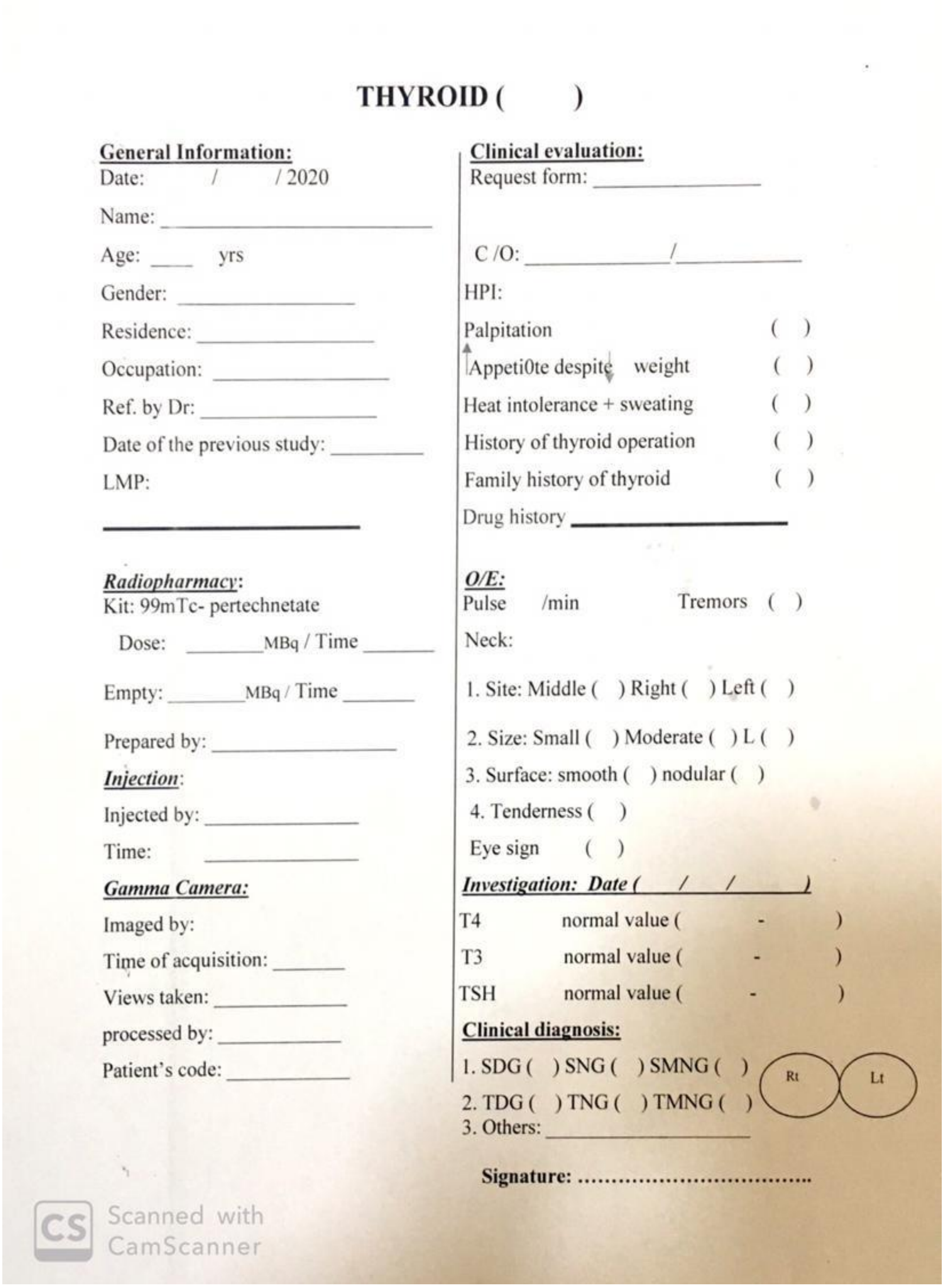
Appendices



THYROID (   )

General Information:

Date: / / 2020

Name: ____________________

Age: ____ yrs

Gender: ______________

Residence: ______________

Occupation: ______________

Ref. by Dr: ______________

Date of the previous study: ________

LMP:

____

***Radiopharmacy*:**

Kit: 99mTc- pertechnetate

Dose: _______MBq / Time _______

Empty: _______MBq / Time _______

Prepared by: ______________

***Injection*:**

Injected by: ______________

Time: ______________

Gamma Camera:

Imaged by:

Time of acquisition: _______

Views taken: ___________

processed by: ___________

Patient's code: ___________

Clinical evaluation:

Request form: ______________

C /O: ____________/____________

HPI:

Palpitation ( )

Appeti0te despite weight ( )

Heat intolerance + sweating ( )

History of thyroid operation ( )

Family history of thyroid ( )

Drug history ______________

O/E:

Pulse /min Tremors ( )

Neck:

1. Site: Middle ( ) Right ( ) Left ( )
2. Size: Small ( ) Moderate ( ) L ( )
3. Surface: smooth ( ) nodular ( )
4. Tenderness ( )

Eye sign ( )

Investigation: Date (/ /)

T4 normal value (-)

T3 normal value (-)

TSH normal value (-)

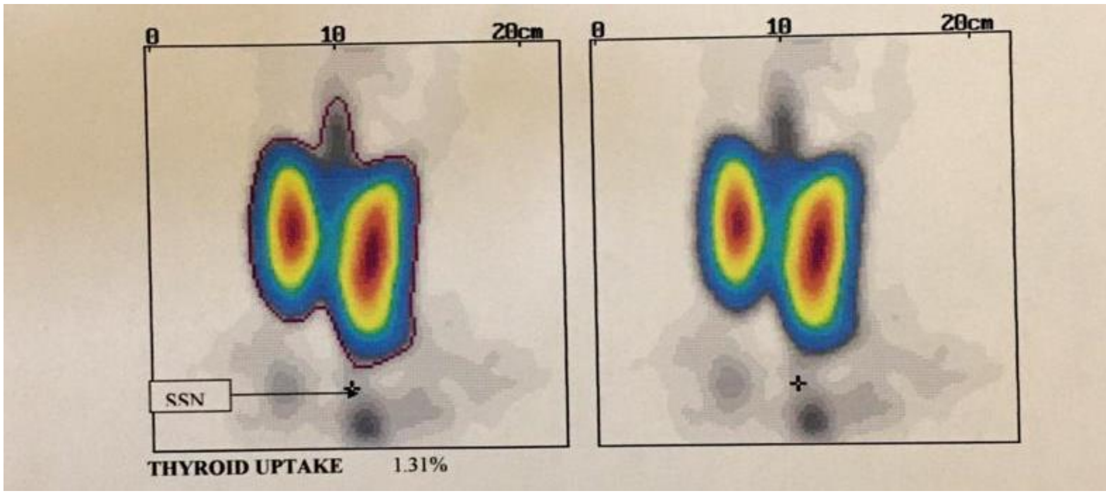
Clinical diagnosis:

1. SDG ( ) SNG ( ) SMNG ( )
2. TDG ( ) TNG ( ) TMNG ( )
3. Others: ______________

Rt Lt

Signature: ....

Appendix (A): show the Clark formula for thyroid uptake



Appendix (B): show an image of thyroid uptake with Technisium-99m