Evaluation of the Image Quality by using MEGP and HEGP Collimators for Iodine-131 in Planar Imaging

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DECLARATION

I hereby declare that this dissertation in the results for my own investigations. I grant Universiti Sains Malaysia the right to use the dissertation for teaching, research, and promotional purpose.

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Date: June 2024

ACKNOWEDGEMENT

As I finally start to write this acknowledgement, I find myself at this moment going to finish studying at the USM Health Campus for my undergraduate journey. This amazing journey started in the fall of 2020 and ends in the summer of 2024, when I just had my 22nd birthday. Now, I would like to express my heartfelt gratitude toward everyone who helped me with my accomplishment of this thesis.

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LIST OF ABBREVIATION

CT	Computed Tomography
SPECT	Single Photon Emission Tomography
SPECT/CT	Single Photon Emission Computed Tomography
ROI	Region of Interest
^{131}I	Iodine-131
SNR	Signal to Noise Ratio
MEGP	Medium-Energy General Purpose collimator
HEGP	High Energy General Purpose collimator
LEHR	Low Energy High Resolution collimator
MEHR	Medium Energy High Resolution collimator
HEHR	High Energy High Resolution collimator
Std. dev	Standard deviation
MRI	Magnetic Resonance Imaging
PET	Positron Emission Tomography
PMT	Photomultiplier tube
ADC	Analog to digital circuit
Bq	Becquerels
FDA	Food and Drug Administration
%CV	percent Coefficient of Variation
FWHM	Full Width at Half Maximum
2D	two-dimensional
DPI	Dots per inch

ABSTRACT

Purpose: High-energy general-purpose (HEGP) collimators are mostly used for iodine-131 in SPECT and planar imaging, while medium-energy general-purpose (MEGP) collimators are seldom used due to the high radiation of iodine-131. In this study, we evaluated the image quality by using MEGP and HEGP collimators with different activities of iodine-131 in planar imaging. Aspects of image quality evaluated include sensitivity, contrast, signal-to-noise ratio, and resolution.

Materials and methods: To scan the iodine-131 in several activities, three petri dishes were used to contain iodine-131. Each petri dish contained 0.2 mCi, 0.4 mCi, and 0.6 mCi of iodine-131, and saline was also added to the petri dish. The planar technique produces static images of petri dishes with iodine-131 from two detectors, and then the information about the petri dishes and background were measured in Xeleris workstation. Based on the specific formulas, sensitivity, contrast, SNR, and resolution were calculated.

Results: Sensitivity in the MEGP collimator is higher than that in the HEGP collimator, while SNR for the HEGP collimator is higher than that in the MEGP collimator. As for resolution and contrast, the MEGP and HEGP collimators show almost similar but still slightly different results in the generated images.

Conclusion: All in all, MEGP and HEGP collimators have their own strengths in image quality using low-activity of iodine-131. Sensitivity in the MEGP collimator is better, and SNR in the HEGP collimator is better.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Medical imaging refers to a number of different techniques which are used to view the human body to diagnose, monitor, or treat disease. Each imaging technique provides different information about the body being diagnosed or treated. This information is crucial in identifying clues to possible disease, injury, or medical treatment. These techniques include CT, ultrasound imaging, magnetic resonance imaging (MRI), X-ray imaging in radiology, single photon emission computed tomography (SPECT), positron emission tomography (PET) in nuclear medicine, and some radiation therapy techniques. (Hussain et al., 2022) Nuclear medicine is a branch of medical imaging that use radioactive tracers to monitor, diagnose, and treat disease. These carefully constructed cameras allow doctors to track the course of radioactive tracers. (“Nuclear Medicine,” 2016) SPECT and PET scans are two of the most common imaging modalities used in nuclear medicine.

Both SPECT and PET scans create three-dimensional (3D) images. The major difference between SPECT and PET scans is the type of radioactive tracer employed. SPECT scans measure gamma rays, whereas PET scans radioactive tracers that decay to produce positrons. (“Nuclear Medicine,” 2016)

The main purpose of PET scans is to detect cancer and monitor its progression, response to treatment. PET/CT scanner is a combination instrument that can perform PET and CT scans of the same body part, and it has become the primary imaging technique for most cancers worldwide. (“Nuclear Medicine,” 2016)

In this study, we used the SPECT/CT gamma camera to scan an iodine-131 filled in a petri dish via planar technique. Single-photon emission computed tomography (SPECT) imaging is a nuclear imaging modality frequently used in diagnostic medicine, providing significant insights into body function processes. SPECT scans are primarily used to diagnose and track the progression of heart disease nowadays. SPECT agents have also recently begun to be used to aid in the diagnosis of disease in the brain. With technological innovation and integration, SPECT/CT is produced as a combination of a SPECT scan and a CT scan. SPECT scans use radioactive tracers injected intravenously, while CT scans use X-ray radiation to provide detailed images of the anatomy inside the body of the patient. By combining the two scanning and resulting in imaging, a patient's anatomy and physiology can be displayed to create a very detailed and informative study. The combination of SPECT and CT can be used to help avoid, detect, and treat a variety of abnormalities in the body. Most times, SPECT/CT scan can identify disease, even at an early stage before other imaging tests can be used. Due to these advantages, the SPECT/CT technique is widely used in nuclear medicine. (“SPECT-CT Scan | University Radiology Associates, LLP | SUNY Upstate,” 2024)

The quality of a SPECT/CT scan depends mainly on the quality of the image obtained. Image quality in all imaging techniques refers to the accuracy of the diagnosis, which is a tough quantity to measure. In nuclear medicine, image quality reflects the imaging technique's ability to detect variations in radioisotopes within the organ.

1.2 PROBLEM STATEMENT

In the SPECT/CT gamma camera scanning, the collimator stands between the patient and the scintillation crystal, which is made up of folded or perforated lead. It aims to collimate the gamma ray emission and restrict the imaging field of view (FOV). Thus, it gathers spatial data regarding the distribution of radioactivity and make it possible for the gamma camera to pinpoint the radioactivity within the patient's body. Various radioactive sources employ different collimators with each property based on its energy peaks, thus producing different image quality.

This study focuses on iodine-131 in SPECT/CT gamma camera with medium-energy general-purpose (MEGP) and high-energy general-purpose (HEGP) collimators for planar imaging. Iodine-131 emits a high radiation energy of 364 keV. Usually, Iodine-131 can be used with high-energy collimators and medium-energy collimators due to iodine-131's high radiation energy. Medium-energy collimators have an energy of around 200- 300 keV, while high-energy collimators are usually used for iodine-131. However, image quality is a challenge when using a MEGP or HEGP collimator with iodine-131. Thus, MEGP and HEGP collimators were used for iodine-131 imaging in this test.

In imaging with high-energy iodine-131, there is an increased risk for septal penetration. This will reduce image contrast and induce artifacts. To minimize these effects, a high-energy collimator is used.

In the collimator, septa are used to absorb most of the gamma rays that do not emanate from the direction of interest. (Mettler and Guiberteau, 2012) Thus, high-energy collimators use thicker septa with a lower number of holes than medium-energy collimators. Thick septa reduce the septal penetration, sensitivity, and count detection, then affect the contrast, SNR, and resolution in the image quality of SPECT/CT planar imaging.

Using the HE collimator, only photons that travel at a specific angle will be absorbed by the septa, and some energy might be blocked, thus causing a sensitivity-resolution trade-off. Relative to these limitations, a low-energy collimator can compensate with the high-count sensitivity, superior spatial resolution, and more holes, especially for the low-spectrum energies portion emitted by iodine-131.

Current practice in nuclear medicine is that used for iodine-131 is a HEGP collimator, but some of the energies might be blocked if it is only a small angle and valuable for image formation. Low activity of iodine-131 in clinical practiced might be compensated with a medium-energy collimator, where scattered and low-energy spectrums might be able to be blocked with only thin septa. Moreover, more holes available due to thinner septa compare to HEGP collimator give more chances for MEGP collimator for through-event, which increases the sensitivity, that might lead to increase the SNR and trade-off the image resolution. However, there is a lack of research studies using MEGP for iodine-131 planar imaging because its energy peak is 364 keV, and iodine-131 is always considered to have high energy radioactivity. Also, medium-energy collimators are avoided due to their high cost compared with other collimators.

1.3 AIM OF STUDY

This study aims to evaluate the image quality by using the MEGP and HEGP collimators for different activities of iodine-131 in SPECT/CT planar imaging. This objective can be further divided into the following objectives:

- To prepare the petri dishes with different activities of iodine-131
- To evaluate the image quality by using MEGP and HEGP collimators, based on sensitivity, contrast, SNR, and resolution.
- To analyze the data obtained statistically.

Moreover, this study has two main hypotheses: there is an important relationship between the contrast, signal-to-noise ratio, and resolution in SPECT/CT planar imaging and the use of different energy collimators, and there is a correction effect between the effects of different energy collimators on SPECT/CT planar imaging.

Therefore, it is necessary to conduct research about the evaluation of the image quality using the SPECT/CT gamma camera, different energy collimators and different activities of iodine-131. The findings of this research might lead to an improved setup for SPECT/CT planar imaging with iodine-131, improving the image quality of iodine-131 scanning and enhancing the accuracy of diagnostics and treatment. Moreover, it will be helpful to use a suitable energy collimator with a special radioactive source based on imaging needs.

CHAPTER 2

LITERATURE REVIEW

2.1 INRODUCTION

Medical imaging is a major technology used in medicine to diagnose, treat, and monitor diseases, while SPECT/CT technique is the most widely used imaging technology in nuclear medicine. ("Nuclear Medicine," 2016) SPECT/CT combines SPECT and CT technologies, using radioactive tracers to diagnose a patient's anatomy and physiology in detail and to treat some diseases. Iodine-131 is one of the radioactive tracers used mainly for thyroid cancer in SPECT/CT. It can be seen that the imaging results of the SPECT/CT technique and iodine-131 are of great significance to both doctors and patients. Among them, the settings of the SPECT/CT technique and the iodine-131 activity will have a great impact on the imaging. Iodine-131 is determined according to the patient's imaging examination needs, so SPECT/CT gamma camera is the only variable that can be changed. In SPECT/CT gamma camera, the performance of the collimator can affect the imaging results.

At present, most of the research on image quality involves how to choose the appropriate energy collimator to match the appropriate radiation source for SPECT/CT imaging purposes, while there are few studies comparing the imaging quality of medium and high energy collimators with iodine-131. This paper will focus on the image quality of two energy collimators with three different activities of iodine-131.

The relevant research mainly focuses on ME and HE collimators using the specific activity of iodine-131.

This chapter 2 literature review mainly introduces some simple theoretical foundations, including the SPECT/CT planar imaging and gamma camera's working principle, radioiodine therapy and scintigraphy. More importantly, it also introduces several similar experimental studies and results related to this study, providing an experimental basis for this study.

2.2 PLANAR, SPECT AND SPECT/CT

SPECT was introduced first by Kuhl and Edwards in 1963. (Hutton, 2014). and the clinical SPECT/CT was developed by Hasegawa and colleagues in the early 1990s for the purpose of technological innovation, which provided the basis for the first release of the SPECT/CT technique in 1999. This technique aims to help the clinician assess the perfusion and functionality of specific organs using a special radiotracer that will be injected through the vein. (Yandrapalli and Puckett, 2022)

The SPECT/CT technique consists of a gamma camera, a CT scanner, a couch, and the control panel. Among these components, the gamma camera is the most essential part of SPECT/CT technique. The components that are integrated and housed into the Gamma Camera Head include a collimator, scintillation detector, photomultiplier tube (PMT), light guide, and pre-amplifier. ("Other Imaging Modalities," 2014) As shown in the introduction in Chapter 1, the collimator aims to collimate the gamma-ray emission and define the direction of the ray, which consists of septa and various holes. For the gamma rays that travel in the wrong direction, they will be absorbed by the collimator before reaching the detector. The function of a scintillation detector is to detect the gamma ray; usually, it is a NaI crystal in a rectangular shape. After absorbing the gamma camera, this scintillation detector will flash. And there are many inorganic materials that can be used for this detector. The light guide, as its name suggests, aims to guide the light to the right position in the PMT. It helps to increase light collection efficiency and improve the uniformity of light collection. The last component inside the gamma camera is photomultiplier tubes (PMTs), which multiply the electrons. The preamplifier aims to preamplify the signal from PMT. This electronic amplifier amplifies, matches impedance levels between the detector and other components in the system, and shapes the signal pulse for signal processing. The components outside the gamma camera are an amplifier, an analog-to-digital (ADC) circuit, a pulse height analyzer (PHA), and a computer interface. The amplifier has two main functions, including amplifying the still relatively small pulses and reshaping the slow decaying pulse from the PMT. As for the analog-to-digital (ADC) circuit, its purpose is to convert analog to digital signals. The pulse height analyzer (PHA) helps to discriminate the summing signal, which also means it analyzes amplitudes and selects only those of desired energy based on the appropriate energy peak and window settings. Lastly, the computer interface aims to form and display the scintigraphy images on the computer. Other components in a computer are the CPU, memory, input device, and output device. Fig. 2.1 is the image of each component's location in the gamma camera.

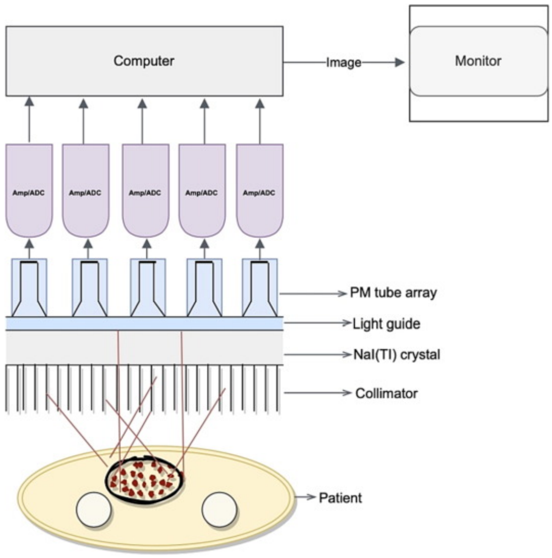

Fig. 2.1: Basic components of gamma camera and their positions. (Alqahtani, 2023)

In the working principle of SPECT/CT imaging, the patient is first injected with a radionuclide into the vein; sometimes patients also swallow or inhale it as a gas. The radionuclide emits gamma rays that will travel in all directions in the patient's body. A part of the radiation travels toward the gamma camera, and a small part of the radiation travels at the correct angle to the collimator and hits the crystal. When a gamma photon hits the crystal, a photon is generated, which is then converted into an electrical signal and amplified by a photomultiplier tube (PMT) and further amplified by a preamplifier. (McKeighen, 1980) An analog to digital circuit (ADC) then converts the signal. A correction circuit then corrects for errors in the positioning and energy of the interaction. (Bushberg et al., 2011) The Z signal passes through a pulse height analyzer (PHA) and is then sent to a computer. Finally, the X, Y, and Z signals are processed and displayed on a computer. (Allisy-Roberts and Williams, 2007) Then the control panel gets the resulted images, and these images can be analyzed and edited in Xeleris workstation.

The above shows that gamma cameras have various main components, which also means that every component can affect the image production inside gamma cameras. Each component has its own specific influence on the image quality, whether it improves or reduces it. In the gamma camera, the replaceable parts include the collimator and crystal material, while the others are fixed.

This study uses planar imaging with a SPECT/CT gamma camera, which refers to obtaining a two-dimensional nuclear image. In planar imaging, the detector doesn't move during scanning. The 2D images obtained are like images taken by a CT scan. Planar imaging produces three types of images, including static, dynamic, and gated images. Static images are used for studies where the distribution of radiopharmaceuticals is effectively static throughout the acquisition process. Static images provide information about organ size, shape, and position. Dynamic images are used to study rapid changes in the distribution of radiopharmaceuticals over time, while gated images help to study organs with regular physiological movements. ("Planar imaging - Radiology Cafe," 2021) In this study, static planar images of iodine-131 will be obtained, and subsequently, image analysis will be performed and data will be compared.

Several studies tested planar imaging with iodine-131. Yusuke conducted a study in 2021 which evaluated the feasibility of quantifying iodine-131 accumulation in scintigraphy images and compared planar and SPECT images. (Iizuka et al., 2021)

The study used 72 pairs of planar and SPECT images acquired and used a capsule of iodine-131 placed next to the patient as a reference for image analysis. Next, the correlation between capsule intensity and dose was evaluated experimentally. The mean capsule activity was 2.14 MBq. The capsule activity in planar images and SPECT images were 0.93, 0.96, 0.60, and 0.47, respectively. Meanwhile, as the correlation coefficients between the mean intensities increased, the p values were all lower than 0.01. The finding suggests that planar images reflect radiation doses more accurately than SPECT images. Therefore, this study compared the image quality in planar imaging.

2.2.1 COLLIMATORS

There are five fundamental collimator types that allow you to choose between imaging speed and quality, magnify or minimize images, and channel photons of various energies. Fig. 2.2 is the image of four types of collimators. These collimators can be divided into several types according to their structure of holes, including parallel hole collimators, slant hole collimators, converging and diverging collimators, fan beam collimators, and pinhole collimators. Parallel hole collimators' holes are parallel to each other, while a slant hole collimator is a variation of a parallel hole collimator where all holes are tilted at a specific angle. This creates a unique view, thus allowing for better visualization of specific organs. In a converging and diverging collimator, the holes are not parallel but focused on the organ. Fan beam collimators are designed for rectangular cameras and are often used to image smaller organs such as the brain and heart, while pinhole collimators have a single hole. According to the applicable radiation energy, it can be divided into low-energy collimators, medium-energy collimators, and high-energy collimators. ("Designs: Collimators for Nuclear Medicine," 2021.)

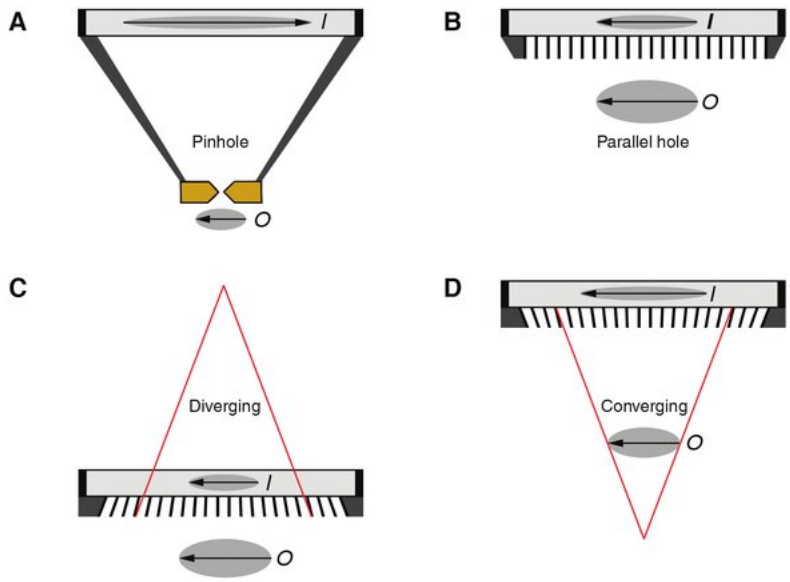

Fig. 2.2: A, B, C and D are the four types of collimators. O is the radioactive project, and I is the projection of object. (Ivashchenko, 2017)

In chapter 1, it was introduced that each energy collimator has a specific applicable energy range, and they also have their own advantages in image quality. These energy collimators include low-energy high-resolution (LEHR) collimator, high-energy high-resolution collimators (HEHR), medium-energy high-resolution (MEHE) collimators, and MEGP and HEGP collimators used in this study. The collimator used is critical to image quality, as the high-energy photons emitted by iodine-131 can cause starlight artifacts. (Mourik et al., 2023)

Therefore, it is a challenge to select a suitable collimator to obtain the image quality with special requirements. Better-quality images are very beneficial for diagnosis and treatment in SPECT/CT scanning.

2.3 RADIOIODINE THERAPY AND SCINTIGRAPHY IMAGING

Iodine-131 was discovered by John Livingood and Glenn Seaborg in 1938. It was prepared by the irradiation of tellurium. Also, iodine-131 has a half-life of 8 days. In 1946, Samuel M. Seidlin, Leo D. Marinelli, and Eleanor Oshry successfully treated a patient with thyroid cancer using iodine-131 for the first time. Since 1947, iodine-131 has been used to detect brain tumors, image blood pools in the heart, measure cardiac output, and image the liver. In 1951, the U.S. Food and Drug Administration (FDA) approved iodine-131 for its use in the treatment of thyroid patients. It was the first FDA-approved radiopharmaceutical. ("Historical Timeline - SNMMI," n.d.)

As a radioisotope, iodine-131 releases gamma rays that can be detected by a specialized gamma camera. This process is known as scintigraphy. Especially, iodine-131 scanning is an essential imaging method for identifying and managing thyroid conditions. The human's thyroid gland can absorb all types of iodine. Therefore, iodine-131 can be used to diagnose and treat thyroid cancer. In patients with differentiated thyroid carcinoma, scans before and after treatment can help better monitor the disease and help doctors choose the best course of action. (Yavuz and Puckett, 2023) Thus, iodine-131 scanning with a high-level image quality can greatly improve the imaging technique's ability.

Iodine-131 is mostly used in the nuclear medicine aspect. It is known to cause the death of the cell that it penetrates and all other cells several millimeters away. For this reason, iodine-131 is used to treat hyperthyroidism (overactive thyroid) and certain thyroid cancers that absorb iodine. Iodine-131 can also be used for imaging purposes because it emits high-energy gamma rays and can be used as a radiolabel for certain radiopharmaceutical therapies.(Deshmukh et al., 2016) Nodules absorb iodine, resulting in them appearing darker or lighter in the image. If a nodule has not absorbed iodine, it will be lighter in the image. If a portion of the thyroid seems lighter, it could indicate a thyroid disease. These mean that iodine-131 can be widely used both for imaging and treatment. ("Thyroid scan: MedlinePlus Medical Encyclopedia," 2022) Moreover, study have shown that Iodine-131 SPECT/CT imaging can be used as a long-term follow-up tool in patients with papillary thyroid microcarcinoma. (Spanu et al., 2018)

Iodine-131 can be used for treatment; however, it also has side effects if taken too much. Adverse effects of using iodine-131 include bone marrow toxicity, salivary gland swelling and tenderness, nausea, vomiting, dry mouth, and hypothyroidism. (Pashnehsaz et al., 2016) Due to the several side effects, the activity of iodine-131 used in nuclear medicine is strictly controlled, and the activity is determined by the diagnostic and therapeutic objectives and the target image quality.

Based on the above information, it is clearly known that iodine-131 imaging is quite important with its special characteristics; thus, the image quality in iodine-131 imaging is also essential.

2.4 RELATIVE RESEARCH – MEGP VS HEGP

Because of its high energy, iodine-131 is typically imaged with HE collimators. However, to address the artifacts of iodine-131 imaging, ME collimators can be used to avoid such artifacts, although they are less common and generally provide lower spatial resolution. (Mourik et al., 2023)

There were several studies that compared the HE and ME collimators with iodine-131 using various phantoms.

The first study by Kobayashi was named "Comparison between a high- and medium-energy collimator for $Na^{131}I$ imaging of differentiated thyroid cancer." (Kobayashi et al., 2013) The test only used an acrylic container as the phantom and four different activities of iodine-131 to do whole body scan and SPECT imaging and got the full-width at half maximum (FWHM) and percent coefficient of variation in the result. The resulting parts can be divided into two imaging objectives. In the simulation of lymph node metastasis, there was almost no difference between the images obtained by the HEGP and MELP collimators. Secondly, for the simulation of the thyroid bed, the HEGP collimator's ^{131}I imaging results showed better image quality than the MELP collimator. And in the case of lower iodine-131 radioactivity, the HEGP collimator can produce better images than the MEGP collimator. In conclusion, this study found that the MEGP collimator can also be used for iodine-131 imaging of the thyroid, although the HEGP collimator is a suitable collimator for iodine-131 imaging.

The same author Kobayashi has one similar study in 2014, which is about "Application of a medium-energy collimator for iodine-131 after ablation treatment of differentiated thyroid cancer." (Kobayashi et al., 2014) This research used both phantoms and patients' data. It scanned phantoms and patients with iodine-131 using the HEGP and MELP collimators, then got the FWHM and %CV, which are the same as his previous study did. This study did whole-body imaging and SPECT imaging of the extrathyroidal bed. In whole-body imaging of the extrathyroidal bed, the FWHM and %CV of the MELP collimator were similar to those of the HEGP collimator, but whole-body imaging with collimators could only identify the extrathyroidal bed with higher radioactivity. In SPECT imaging, the %CV of the MELP collimator was significantly higher than that of the HEGP collimator, and the FWHM results were similar. In conclusion, WB imaging with the HEGP collimator and SPECT with both collimators could detect the extrathyroidal bed, but whole-body imaging with the MELP collimator detected the extrathyroidal bed. Based on these results, this research concluded that ME collimators were able to identify extra-thyroid beds with higher radioactivity levels. Overall, both collimators could detect extra-thyroid beds in patients, but HE collimators were slightly more effective in some cases.

In the third research by Wesley Wooten and Tri Tran, they did the test that compared the MEGP collimator to a HEGP collimator with iodine-131 for the special task of lesion detection. (Wooten and Tran, 2010) This study used one phantom with one activity of iodine-131, then drew up data within different scan durations and compared them. The resulted data includes FWHM/FWTM, total CPM, collimated

CPM, and minimum detectable time. The resulting images show that the septum penetration of the MEGP collimator is reflected in its high FWTM data. The total count sensitivity of the MEGP collimator is 2.3 times higher and 1.6 times higher than the "properly collimated" counts. Moreover, the resulting images also show that for the same lesion size, lesion activity, and scan duration, all lesions detectable by the high-energy collimator can also be detected by the medium-energy collimator. And the findings show that MEGP and HEGP collimators have the same ability to identify lesions in thyroid imaging.

Another study by Jung Yul Kim in 2014 compared the image quality of iodine-131 SPECT/CT scanning using the HE and ME collimators in the NEMA NU-2 IQ phantom with an iodine-131 point source. (Kim et al., 2014) From the resultant data, the sensitivity of the ME collimator is much higher than that of the HE collimator. Under the same conditions, the contrast of the ME collimator is lower than that of the HE collimator. However, if a reasonable energy window, matrix size, IR parameters, CTAC, and scatter correction are used, the ME collimator is also applicable under the conditions of a small radiation dose and low sensitivity. This study found that the HE collimator is the most suitable collimator when used with iodine-131, while the ME collimator is also applicable for lower doses and is less sensitive.

These similar but different experiments all came to a similar conclusion: both ME and HE collimators can be used for iodine-131, and they have each characteristic.

2.5 RESEARCH GAP

The previous experiments all tested the impact of ME and HE collimators on image quality using simulations of phantoms and patient data. They mostly measured FWHM, %CV, sensitivity, and counts in resulted image quality and used whole-body imaging and SPECT imaging.

All researchers also came to similar conclusions: collimators with different characteristics have a great impact on image quality, and both HE and ME collimators can be used for iodine-131 imaging. Currently, most of the existing studies focus on clinical scanning, using the same activity of iodine-131 to study and compare the differences between medium-energy and high-energy collimators. The first two experiments from Kobayashi mentioned only studied the field of thyroid cancer, and the third experiment by Wesley Wooten and Tri Tran only studied the specific objective of lesion detection, both of which focused on specific imaging targets. A considerable body of research has mostly been carried out on the differences between medium-energy and high-energy collimators when scanning the same activity of iodine-131 in clinical practice. Much less is known about the differences in image quality using medium-energy and high-energy collimators with different activities of iodine-131 in petri dishes. According to previous studies, the limitations of collimators with different energy levels and radiation sources for different activities are becoming apparent, and the research content of comparable image quality with more details has not been studied.

CHAPTER 3

MATERIALS AND METHODOLOGY

3.1 MATERIALS

3.1.1 SPECT/CT

The SPECT/CT gamma camera machine in HUSM is the Discovery NM/CT 670 Pro as shown in Fig. 3.1, equipped with dual gamma detectors. It also includes the latest diagnostic CT technology, a 16-slice system with IQ enhancement technology. The SPECT/CT technique usually obtains dynamic images of the injected radioactive source in the human body. However, in this study iodine-131 was only placed in the petri dish for the planar imaging, to produce a static planar image for certain total counts set-up.

Fig. 3.1: Discovery NM/CT 670 Pro in HUSM

3.1.2 PETRI DISH

A petri dish is a container, usually made of flat glass or plastic, that has a variety of uses in medical laboratories. They are primarily used as laboratory equipment in the fields of biology and chemistry to culture cells, provide storage space, and protect cells from contamination. But in this experiment, petri dishes were used as containers to store iodine-131 for scanning and imaging, as shown in Fig. 3.2. This is partly because iodine-131 has a short half-life of 8 days, and other reasons include the low cost and high efficiency of petri dishes.

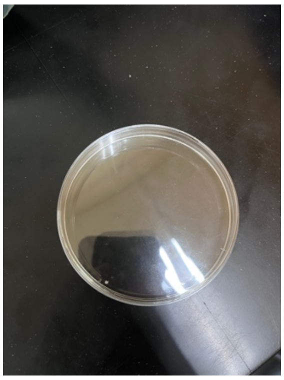

Fig. 3.2: Petri dish used in this study.

3.1.3 DOSE CALIBRATOR

Because humans cannot see or feel radiation, we cannot measure radiation directly. However, we can measure it indirectly by measuring its effects with instruments because invisible nuclear radiation creates electrical effects or ionization in the materials it passes through that we can measure.

A radioisotope dose calibrator is one of those tools that used to measure the activity level of a syringe, vial, etc. containing a substance that is about to be injected into a patient. This instrument is often used in nuclear medicine to determine the exact activity of the radioactive dose a patient is receiving, expressed in becquerels (Bq). Dose calibrators typically have a sealed chamber whose purpose is to reduce and eliminate the effects of changes in gas pressure on the output reading. A dose calibrator consists of a gas-filled shell between two electrodes (an anode and a cathode). X-rays or gamma photons ionize the gas in the sample holder. At the same time, a large voltage difference is applied to the electrodes in the chamber. The voltage difference causes the ions and dissociated electrons to move to the electrodes of opposite polarity, thus generating a voltage pulse. Using electronic circuits, this voltage pulse is converted into an electric current that can be measured. Each ion essentially deposits or removes a small amount of charge on an electrode, so the accumulated charge is proportional to the number of ions with the same charge. Fig. 3.3 is the image of the components of the dose calibrator.

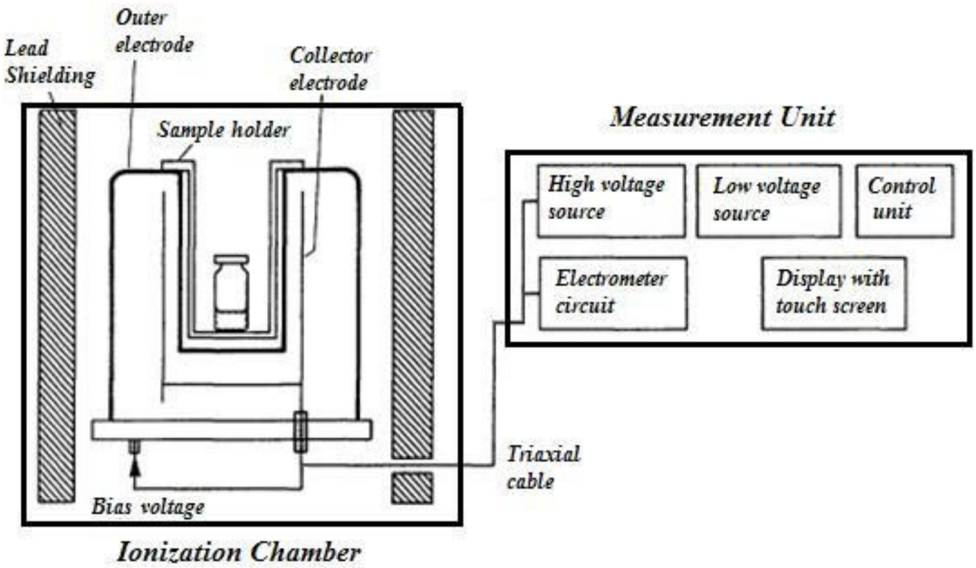

Fig. 3.3: Dose calibrator components. (Javier and Romeu, n.d.)

3.1.4 IODINE-131

Iodine-131 is produced by the fission of the Uranium-235 isotope, as shown in Fig. 3.4. Iodine-131 is a radioactive isotope of iodine with an atomic mass of 131, and a half-life of 8.06 days. It has an energy peak at 364 keV. Iodine-131 decays by emitting beta particles, becoming xenon-131, as shown in Fig. 3.5.

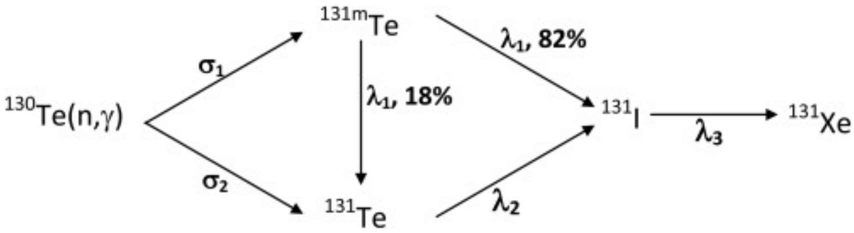

Fig. 3.4: Production of iodine-131.

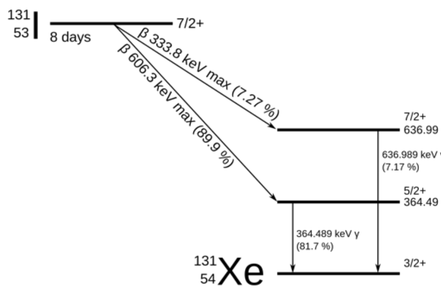

Fig. 3.5: Decay scheme of iodine-131.

Medically, iodine-131 is supplied in capsules or liquid form for patients to swallow. But as a product of nuclear fission, it is a dark purple gas that can be inhaled or absorbed through the skin. Iodine-131 can go directly from solid to gas, skipping the liquid phase, a process called sublimation. ("Iodine-131 | Radiation Emergencies | CDC," 2024)

3.2 METHODOLOGY

3.2.1 IODINE-131 PETRI DISH PREPARATION

To perform tests with MEGP and HEGP collimators, the petri dish (Fig. 3.6 A) plays a significant role in containing iodine-131. Comparing with other phantoms, the petri dish is easy to handle and operate when dealing with high-radioactivity sources such as iodine-131. Scanning petri dishes of different activities of iodine-131, the SPECT/CT gamma camera produces static planar images from both detectors. In the beginning of preparing petri dishes, 20 cc of normal saline was added to each petri dish by a disposable pipette. Saline is used to modify iodine-131. After adding saline to three different petri dishes, 0.2 mCi, 0.4 mCi, and 0.6 mCi of iodine-131 were individually taken from a lead container and then added to three petri dishes. During the preparation of the petri dish, gloves and an electronic personal dosimeter (Fig. 3.6 B) are essential for radiation protection.

A B

Fig. 3.6: A shows three petri dished with 0.2 mCi, 0.4 mCi and 0.6 mCi of iodine-131; B is the electronic personal dosimeter which belongs to radiation protection tools.

3.2.2 IMAGE ACQUISITION

Image acquisition is defined as the act of obtaining an image from a source. This