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Comparison of the Uptake Percentage of Technetium-99m Pertechnetate in Hyperthyroid Patients during Gamma Scintigraphy Examination

Wilson Soetanto[1], Robi Dany Riupassa[1]

[1]Program Studi Fisika, Universitas Matana,
Jl. CBD Barat Kav 1, Tangerang, Banten 15810, Indonesia

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Abstract

Gamma scintigraphy is an examination that can be used to evaluate patients suspected of suffering from hyperthyroidism. This procedure involves administering the radiopharmaceutical Technetium-99m to the patient, followed by imaging using a gamma camera to check the function of the thyroid gland. The resulting image can be analysed using the ROI (Region of Interest) method to measure the percentage of radiopharmaceutical uptake by the thyroid. The aim of this study was to compare the uptake of radiopharmaceuticals in hyperthyroid patients and determine the correlation between uptake values and age and gender factors. This study involved 47 hyperthyroid patients, including 15 men and 32 women, aged between 10 and 75 years. The results showed that the average level of absorption (uptake) of radiopharmaceuticals by the right lobe of the thyroid (7.49% ± 7.41%) was higher than that by the left lobe (6.58% ± 6.31%). Additionally, men showed a higher uptake percentage (17.55% ± 14.34%) compared to women (12.44% ± 12.86%). Another finding was that there was a significant (strong) negative correlation between the uptake value and the patient's age, both in men (r = -0.641, p = 0.00988) and women (r = -0.674, p = 0.00010).

✉ Alamat korespondensi:
Progam Studi Fisika, Universitas Matana
E-mail: wilson.soetanto@student.matanauniversity.ac.id

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INTRODUCTION

Hyperthyroidism occurs when the thyroid gland works too actively, resulting in increased production of thyroid hormone. This has an impact on the speed of metabolism occurring in the body, causing symptoms such as fatigue, trembling hands, drastic weight loss, swollen thyroid glands, and emotional instability (American Thyroid Association, 2023). In 2022-2023, there will be 13.2 million hyperthyroid patients in Indonesia, but only 6.2% of the total cases receive appropriate treatment (Merck Indonesia, 2023).

Gamma scintigraphy is a medical examination that can be used to evaluate hyperthyroidism disorders. As part of nuclear medicine, this procedure involves administering the radiopharmaceutical Technetium-99m to patients who may have hyperthyroidism. After that, imaging is carried out using a gamma camera to visualize the functional condition of the thyroid gland. The resulting scintigraphic image provides information about the accumulation of radiopharmaceuticals in the thyroid gland. This image analysis can be carried out quantitatively using the ROI (Region of Interest) method to calculate the percentage level of absorption (uptake) of radiopharmaceuticals in the thyroid gland (Jin et al., 2021).

Thyroid absorption (uptake) is influenced by several factors such as age, gender, geographical location, amount of iodine consumed in food, and use of certain medications (Malik et al., 2021). Research conducted by Alshahrani (2021) in Saudi Arabia showed that thyroid absorption decreases with age, especially in women ($r = -0.37$) and men ($r = -0.46$). The results of the same study by Güngör (2021) in Turkey also found a negative correlation between age and thyroid absorption ($r = -0.33$) for both men and women. However, these two studies were only carried out on groups of patients with normal thyroid conditions (euthyroid), while research on hyperthyroid patients was still limited.

In this context, research is needed to determine and compare the absorption of radiopharmaceuticals in hyperthyroid patients. This study also aims to identify whether age and gender factors can influence thyroid absorption values. It is hoped that the results of this research will increase the effectiveness of treating hyperthyroid patients by nuclear medicine practitioners, especially medical physicists, in the future.

METHODS

This research is a retrospective study of 47 hyperthyroid patients who underwent gamma scintigraphy examination. Sample selection involved all male and female patients in the age range of 10-75 years. Sample selection criteria were based on a review of literature related to this research. All patients underwent gamma scintigraphy according to the standard protocol established by the Society of Nuclear Medicine and Molecular Imaging (Giovanella et al., 2019). When undergoing examination, hyperthyroid patients are given the radiopharmaceutical Tc-99m pertechnetate intravenously at a dose of 2-5 mCi.

Before the injection of radiopharmaceuticals, the radiation count rate in a full syringe (full syringe cpm) is measured. After administering the radiopharmaceutical, the radiation count rate is measured again on an empty syringe (empty syringe cpm). This measurement process was carried out for 1 minute with a gamma camera and involved ROI (Region of Interest) analysis of the image obtained (Figure 1). A comparison of the two results is needed to determine the net amounts of radiopharmaceuticals (net cpm) that enters the patient's body, by reducing the amount of radiation in the syringe before and after injection. Then, the patient will undergo a scanning process after waiting around 15-20 minutes so that the radiopharmaceutical can be maximally absorbed by the thyroid gland (Laßmann & Hänscheid, 2021).

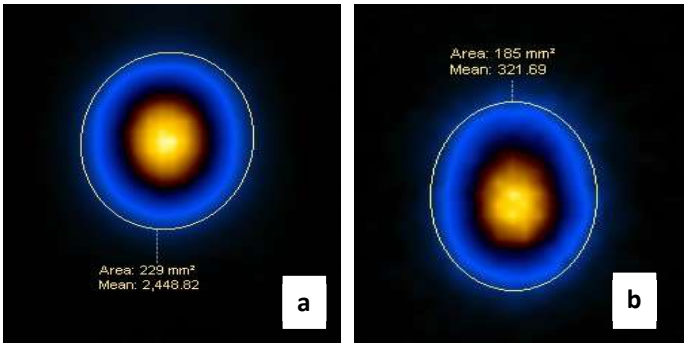

Figure 1. Example of Radiation Count Rate Measurement Results in Injections. Description: (a) Full syringe cpm and (b) Empty Syringe cpm

The gamma scintigraphy examination will be carried out with a gamma camera placed planarly on the neck area for approximately 3 minutes. It should be understood that the working principle of a gamma camera is based on the NaI(Tl) scintillation detector, which functions to capture radiation emitted by radiopharmaceuticals in the patient's body and convert it into an electrical signal. The signal will then be processed digitally, forming an image of the thyroid (Pelletier-Galarneau et al., 2020).

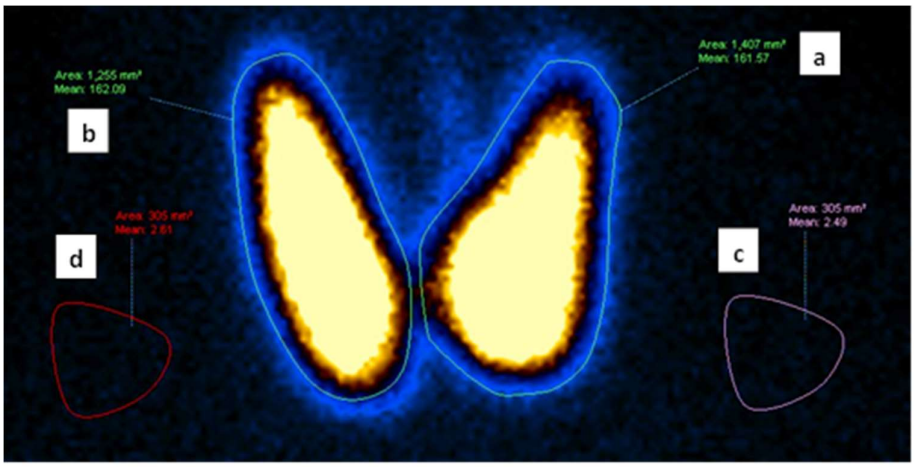

Figure 2. Example of ROI Results on Hyperthyroid Patient Images. Description: (a) Left lobe, (b) Right lobe, (c) Left lobe background, and (d) Right lobe background

Then, an ROI (Region of Interest) analysis will be carried out on the scintigraphy image. This process is performed precisely by tracing the area under review, namely the left thyroid lobe, the right thyroid lobe, and the background for all images of hyperthyroid patients. An example of the ROI results in this research can be seen in Figure 2. Next, the uptake rate of the radiopharmaceutical will be calculated using the following equation.

$$\text{Left thyroid uptake (\%)} = \frac{\text{Left thyroid (cpm)} - \text{Background (cpm)}}{\text{Empty syringe (cpm)} - \text{Full syringe (cpm)}} \times 100\% \quad (1)$$

$$\text{Right thyroid uptake (\%)} = \frac{\text{Right thyroid (cpm)} - \text{Background (cpm)}}{\text{Empty syringe (cpm)} - \text{Full syringe (cpm)}} \times 100\% \quad (2)$$

$$\text{Thyroid uptake (\%)} = \text{Left thyroid uptake (\%)} + \text{Right thyroid uptake (\%)} \quad (3)$$

Descriptive statistics are presented including the mean and standard deviation (mean ± SD), as well as the median in the interquartile range or minimum–maximum values. Next, the data were tested using several statistical methods, including the normality test (Shapiro-Wilk), group comparison test (Mann-Whitney U), and correlation test between thyroid uptake variables and age and gender factors. Statistical analysis was carried out using the Analysis ToolPak feature in Microsoft Excel LTSC Professional Plus 2021 software.The Shapiro-Wilk normality test is used to evaluate whether the data distribution is normal or not. Comparisons between groups were performed using the Mann-Whitney U test to compare two groups and determine whether there were significant differences between them. The selection of this test is based on the imbalance in sample size between men and women and does not depend on data distribution. Next, to assess the correlation between variables, the Pearson or Spearman correlation test is used, depending on the data distribution. The author set the level of statistical significance at $p < 0.05$ to ensure the accuracy of the research results.

RESULTS AND DISCUSSION

In this study, the authors used 47 samples of patients who suffered from hyperthyroidism and had undergone gamma scintigraphy examination. The sample consisted of 15 men and 32 women with an age range of 10-75 years. The age characteristics of the patients are described in Table 1. Based on these data, it was found that cases of hyperthyroidism were more common in women than men. This finding is in line with research conducted by Kanokwongnuwat (2022) in Chantaburi, Thailand, and Ahn (2023) in Seoul, Korea, which stated that women have a 1.6-2.5 times higher risk of suffering from hyperthyroidism compared to men. Additionally, the average age of hyperthyroid patients in this study was 43.55 ± 16.06 years. In this study, male patients had a higher mean age than female patients. However, there was no significant difference in age between men and women ($p = 0.451$), based on the Mann-Whitney U test that was carried out.

Table 1. Descriptive Statistics Results for Patient Age Characteristics (Years)

Patient	Mean ± SD	Median	Range (Min-Max)	P-Value
Male (n = 15)	46.40 ± 15.91	47	20-75	0.451
Female (n = 32)	42.22 ± 16.21	44	10-75	
All (n = 47)	43.55 ± 16.06	45	10-75	-

Comparison of the Percentage of Radiopharmaceutical Absorption in Hyperthyroid Patients

Next, a calculation was carried out on the percentage of radiopharmaceutical absorption in hyperthyroid patients. Uptake values were determined separately for the left lobe, right lobe, and the entire thyroid gland. These data are displayed in Table 2. The calculation results show that the right lobe of the thyroid (7.49 ± 7.41%) provides a higher radiopharmaceutical absorption value compared to the left lobe of the thyroid (6.58 ± 6.31%). This was found in both male and female patients. According to a study by Wagieh et al. (2020), it is known that the right lobe shows higher radiopharmaceutical accumulation than the left lobe in patients with Graves' disease, which is the main cause of hyperthyroidism.

Furthermore, a scientific article released by the Endocrine Surgeon of the UK in 2023 noted the asymmetric structure of the human thyroid gland, with the right lobe tending to be larger than the left lobe (Endocrine Surgeon of the UK, 2023). These factors not only create visual differences but also influence the distribution of blood flow and the number of blood vessels in the area. This may explain why radiopharmaceuticals, which are transported by blood, tend to be more concentrated in the right lobe, resulting in increased uptake values in that part.

Table 2. Calculation results of radiopharmaceutical uptake percentage in the thyroid.

Uptake Value in the Left Lobe of the Thyroid				
Patient	**Mean ± SD**	**Median**	**Range (Q1-Q3)**	**P-Value**
Male (n = 15)	8.62 ± 6.88 %	8.89 %	1.44 – 13.45 %	0.273
Female (n = 32)	5.63 ± 5.90 %	2.92 %	0.96 – 9.91 %	
All (n = 47)	6.58 ± 6.31 %	4.48 %	1.44 – 11.06 %	-
Uptake Value in the Right Thyroid Lobe				
Patient	**Mean ± SD**	**Median**	**Range (Q1-Q3)**	**P-Value**
Male (n = 15)	8.93 ± 7.69 %	10.27 %	1.65 – 12.83 %	0.385
Female (n = 32)	6.82 ± 7.30 %	3.29 %	1.73 – 10.74 %	
All (n = 47)	7.49 ± 7.41 %	5.12 %	1.63 – 11.42 %	-
Total Uptake Value in the Thyroid Gland				
Patient	**Mean ± SD**	**Median**	**Range (Q1-Q3)**	**P-Value**
Male (n = 15)	17.55 ± 14.34 %	19.76 %	3.06 – 26.28 %	0.273
Female (n = 32)	12.44 ± 12.86 %	7.02 %	3.27 – 20.00 %	
All (n = 47)	14.07 ± 13.41 %	10.03 %	3.19 – 21.72 %	-

Table 2 also shows that the average percentage of uptake in male hyperthyroid patients is higher than in female hyperthyroid patients, respectively 17.55 ± 14.34 % and 12.44 ± 12.86 %. This finding is consistent with the results of research conducted by Al-Jabri et al. (2021), which found that the mean thyroid absorption in men was higher than in women, respectively, 9.38 ± 9.25% and 4.99 ± 4.16%. The study states that differences in uptake values between the sexes can be caused by variations in thyroid function, hormonal influences, or differences in metabolic systems between men and women.

Based on the data in Table 2, it is also known that there is no significant difference between the male and female patient groups in terms of the percentage of absorption (uptake) of radiopharmaceuticals in the left lobe ($p = 0.273$), right lobe ($p = 0.385$), and the thyroid gland ($p = 0.273$). The mean value of radiopharmaceutical uptake in hyperthyroid patients was 14.07 ± 13.41%. Research conducted by Kim et al. (2011) determined that the normal range of thyroid absorption values is between 1.7-4%. This means that the uptake value in this study exceeds this limit, indicating increased thyroid gland activity (hyperthyroid condition).

Correlation Testing of Radiopharmaceutical Absorption Percentage in Hyperthyroid Patients.

Afterward, the Shapiro-Wilk test was carried out to evaluate whether the data in the study had a normal distribution. The results of this test are recorded in Table 3. This step is crucial because it is a prerequisite for selecting correlation tests between variables in the next stage. If the data show a normal distribution ($p > 0.05$), then the Pearson test is used; whereas if the data are not normally distributed ($p < 0.05$), then the Spearman test will be used.

Table 3. Data Normality Test Results on Total Uptake Values in the Thyroid

Patient	**Shapiro-Wilk**	**P-Value**	**Distribution**
Male (n = 15)	0.912	$0.1 < p < 0.5$	Normal
Female (n = 32)	0.825	$p < 0.01$	Abnormal
All (n = 47)	0.857	$p < 0.01$	Abnormal

The results of the correlation test between variables are shown in Table 4. The level of significance in this study is $p < 0.05$. The results of correlation testing in this study found that the percentage of absorption (uptake) of radiopharmaceuticals had a significant negative correlation with the age of hyperthyroid patients ($r = -0.674$, $p < 0.00001$). Statistical analysis also showed a significant and strong correlation in both male ($r = -0.641$, $p = 0.00988$) and female ($r = -0.674$, $p = 0.00010$) patient groups. This provides consistent findings that the older the patient, the lower the absorption of radiopharmaceuticals in the thyroid gland, both in men and women. Additionally, women had a stronger significance in terms of the correlation between uptake and patient age. This means that there are differences in the response to absorption of radiopharmaceuticals based on gender. Women have a more significant decrease in uptake with age than men. The correlation test graph has been shown in Figures 3-5.

Table 4. Correlation Test Results Between Uptake Values and Age of Hyperthyroid Patients

Variable 1 (Uptake)	Variable 2 (Age)	Coefficient Correlation (r)	P-Value	Hasil Uji
Pria (n = 15)	Age	-0.641	0.00988	Strong
Wanita (n = 32)		-0.632	0.00010	Strong
Semua (n = 47)		-0.674	< 0.00001	Very Strong

The decrease in uptake values is caused by the reduced ability of the thyroid gland to absorb radiopharmaceuticals as a person ages. This condition affects the absorption of radiopharmaceuticals, especially in hyperthyroid patients who are elderly (> 60 years) (Taylor et al., 2023). These findings are in line with the results of a study reported by Al-Jabri and colleagues in 2022. In this study, they determined and compared uptake values in patients with Graves' disease, which is one of the causes of hyperthyroidism. Through statistical analysis, they revealed that there was a negative correlation between the percentage of thyroid uptake and the patient's age. Furthermore, the results of the study also showed that the correlation between variables was more significant (stronger) in women than in men (Al-Jabri et al., 2022). These findings have confirmed the consistency of the research results conducted by the author with findings in other scientific literature.

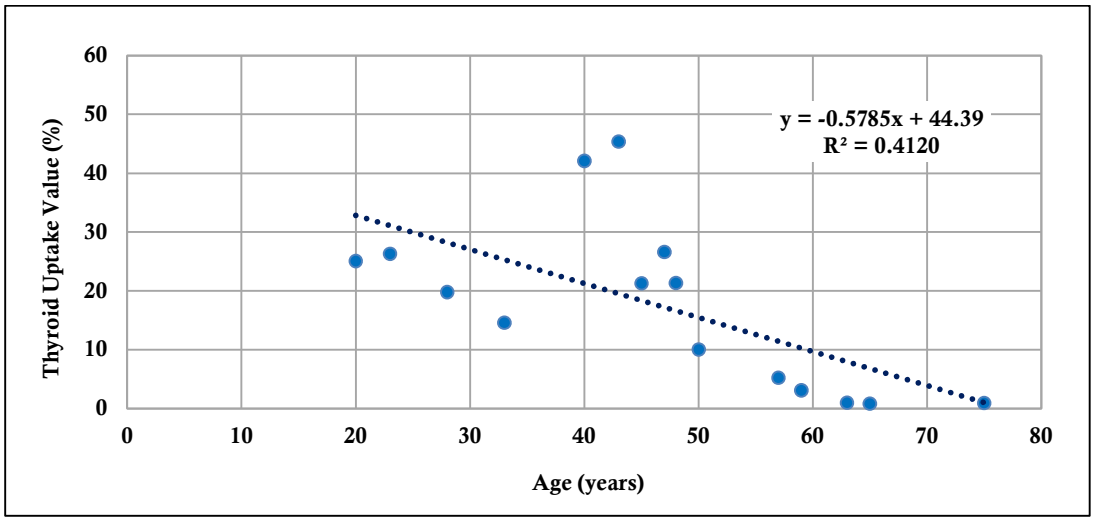

Figure 3. Correlation graph between uptake values and age in male patients

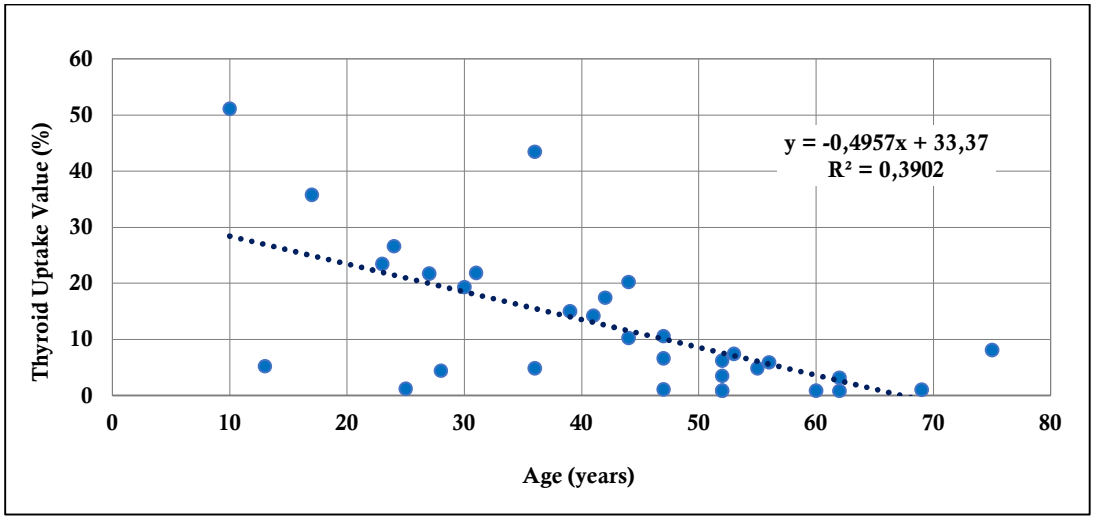

Figure 4. Correlation graph between uptake values and age in female patients

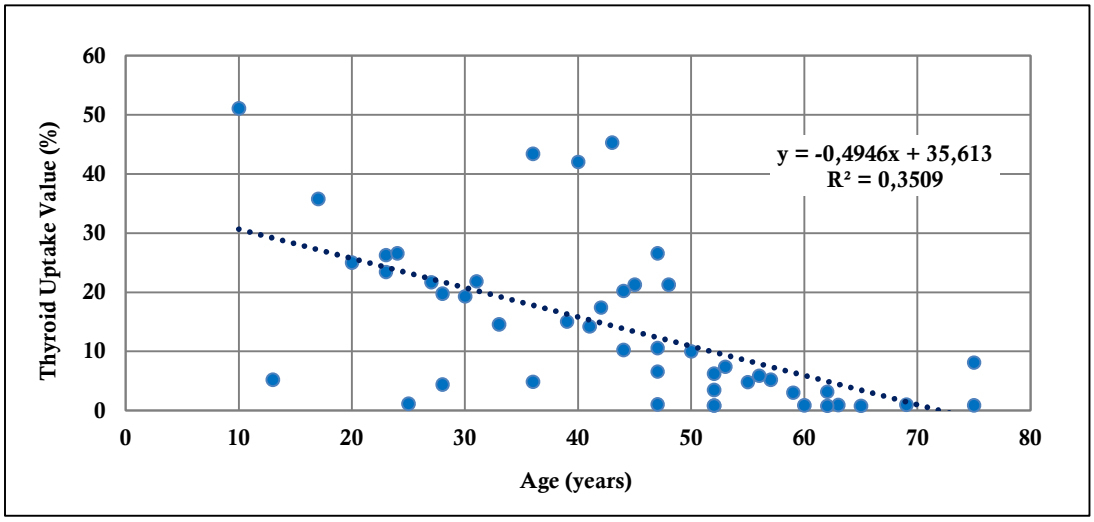

Figure 5. Correlation graph between uptake values and age in all patients

CONCLUSION

Based on the results of this study, it can be concluded that the uptake percentage of radiopharmaceuticals in hyperthyroid patients is influenced by gender and age factors. The uptake value showed a negative correlation with the age of the patient, both in men and women. Additionally, there is a stronger significance in women than in men in terms of the correlation between these variables. It is hoped that this research can provide important information for nuclear medicine practitioners in the more effective treatment of hyperthyroid patients.

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