

Relationship of ^{99m}Tc -Pertechnetate and ^{131}I thyroid uptake in patient with hyperthyroidism

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- Background** : Measurement of the thyroid uptake is usually performed with ^{131}I to determine therapeutic dose in patients treated hyperthyroidism with ^{131}I . ^{99m}Tc -pertechnetate is also trapped by the thyroid gland in a manner and to a degree very similar to iodine. This study may help identify patients who have discordance in diagnostic and radioactive iodine uptake (RAIU), for better management and treatment results. The thyroidal uptake performed by ^{99m}Tc -pertechnetate takes 30 minutes shorter than that performed by ^{131}I for 2 days.
- Objective** : To study the thyroidal uptake by ^{99m}Tc -pertechnetate in relation to RAIU in the same patients and to estimate RAIU at 24hr from ^{99m}Tc -pertechnetate uptake.
- Design** : Prospective and descriptive study.
- Setting** : King Chulalongkorn Memorial Hospital.
- Materials and Methods** : Two hundred and six patients who perform RAIU were enrolled into the study. Images were acquired with LEHR collimator of gamma camera system. Images of the syringe were obtained both before and after radiopharmaceutical injection; the image

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on the injection site was obtained to check for subcutaneous infiltration. The images for anterior thyroid at 5 minutes and 20 minutes after injection were performed. ^{99m}Tc -pertechnetate uptake was calculated from thyroid scan image.

Results : The study showed that RAIU at 24hr were correlation with ^{99m}Tc -pertechnetate thyroid uptakes at 5 and 20 minutes as the following equations: Estimated 24hr RAIU = $14.863 \cdot \ln(\text{Pertechnetate Uptake at 5min}) + 36.741$; $R^2 = 0.744$ Estimated 24hr RAIU = $14.441 \cdot \ln(\text{Pertechnetate Uptake at 20min}) + 34.314$; $R^2 = 0.708$ ^{99m}Tc uptakes at 20min were mostly greater than uptakes at 5min but ^{99m}Tc uptake at 5min showed better correlation than the uptake at 20min. RAIU at 3hr is used to detect early uptake especially in case of rapid turnover and can predict estimated 24-hour Iodine uptake as equation: Estimated iodine uptake at 24hr = $27.43 \cdot \ln(\text{iodine uptake at 3hr}) - 34.233$; $R^2 = 0.85$

Conclusion : ^{99m}Tc -pertechnetate uptake can be used to estimate 24hr iodine uptake but it depends on the acquisition and calculation techniques. This is an alternative method to determine RAI dose.

Keywords : Thyroid uptake, iodine-131, technetium-99m, nuclear medicine, hyperthyroid.

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เทคนิคินเนียมเปอร์เทคนิคิตกับไอโอดีนกัมมันตรังสี ในต่อมไทรอยด์ของผู้ป่วยต่อมไทรอยด์
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เหตุผลของการทำวิจัย : การทำไทรอยด์อ็อปเทคด้วยไอโอดีนกัมมันตรังสีเพื่อนำค่าที่ได้ไป
คำนวณปริมาณความเข้มข้นรังสี เพื่อใช้ในการรักษาโรคต่อมไทรอยด์
เป็นพิษ โดยการดื่มไอโอดีนกัมมันตรังสี ส่วนเทคนิคินเนียมเปอร์เทคนิคิต
จะถูกจับโดยต่อมไทรอยด์เหมือนกับไอโอดีน การศึกษานี้ช่วยจำแนก
กรณีผลการตรวจขัดแย้งกับการวินิจฉัยโรค หรือใช้บริหารจัดการเพื่อ
ให้ได้ผลการรักษาที่ดีแก่ผู้ป่วยการหาค่าไทรอยด์อ็อปเทคด้วย
เทคนิคินเนียมเปอร์เทคนิคิตจะใช้เวลานานกว่ามาก เพียง 30 นาที ขณะที่
การทำไทรอยด์อ็อปเทคด้วยไอโอดีนกัมมันตรังสีจะใช้เวลา 2 วันติดกัน

วัตถุประสงค์ : เพื่อศึกษาความสัมพันธ์ของค่าไทรอยด์อ็อปเทคด้วยเทคนิคินเนียม
เปอร์เทคนิคิตกับไอโอดีนกัมมันตรังสี และใช้ค่าอ็อปเทคจากเทคนิคินเนียม
มาทำนายค่าอ็อปเทคจากไอโอดีนกัมมันตรังสีที่ 24 ชั่วโมง

รูปแบบการวิจัย : การศึกษาวิจัยเชิงพรรณนาไปข้างหน้า

สถานที่ทำการศึกษา : สาขาเวชศาสตร์นิวเคลียร์ ฝ่ายรังสีวิทยา โรงพยาบาลจุฬาลงกรณ์

ตัวอย่างและวิธีการศึกษา : การศึกษาทำในผู้ป่วย 206 รายที่มีการทำไทรอยด์อ็อปเทคด้วยไอโอดีน
กัมมันตรังสี หลังจากวัดไทรอยด์อ็อปเทคด้วยไอโอดีนกัมมันตรังสีที่
24 ชั่วโมงแล้วผู้ป่วยจะทำไทรอยด์สแกนด้วยเทคนิคินเนียมเปอร์เทคนิคิต
การถ่ายภาพจะใช้คอลลิเมเตอร์ที่ใช้กับรังสีพลังงานต่ำและแสดง
รายละเอียดสูง โดยจะมีการบันทึกค่านับวัดกระบอกฉีดยาเทคนิคินเนียม
เปอร์เทคนิคิตทั้งก่อนฉีด หลังฉีด และบริเวณที่ฉีดสารเภสัชรังสีด้วย
หลังฉีดยาแล้วที่ 5 และ 20 นาทีผู้ป่วยจะได้รับการถ่ายภาพต่อมไทรอยด์
หน้าตรง จากนั้นจะนำภาพการทำไทรอยด์สแกนมาคำนวณหาค่าอ็อปเทค

ผลการศึกษา : ผลการศึกษาพบว่าค่าอ็อปเทคจากไอโอดีนกัมมันตรังสีที่ 24 ชั่วโมง
มีความสัมพันธ์กับค่าอ็อปเทคจากเทคนิคินเนียมที่ 5 และ 20 นาที โดยมี
สมการความสัมพันธ์ดังนี้

$$\text{Estimated 24hr RAIU} = 14.863 * \ln(\text{Perchnetate Uptake at 5min}) + 36.741 ; R^2 = 0.744$$

$$\text{Estimated 24hr RAIU} = 14.441 * \ln(\text{Perchnetate Uptake at 20min}) + 34.314 ; R^2 = 0.708$$

ค่าอัปเดตจากเทคนิคซีเอ็มที 20 นาที่ ส่วนใหญ่จะมีค่าสูงกว่าค่าอัปเดตจากเทคนิคซีเอ็มที 5 นาที่ แต่ค่าอัปเดตจากเทคนิคซีเอ็มที 5 นาที่จะมีความสัมพันธ์ที่ดีกว่าในการใช้ประมาณค่าอัปเดตจากไอโอดีนกัมมันตรังสีที่ 24 ชั่วโมงค่าอัปเดตจากไอโอดีนกัมมันตรังสีที่ 3 ชั่วโมงมีความจำเป็นในการวัดต่อมไทรอยด์ที่มีการจับไอโอดีนเร็วและมีการหลั่งไทรอยด์ฮอร์โมนเร็ว นอกจากนี้ค่าอัปเดตจากไอโอดีนกัมมันตรังสีที่ 3 ชั่วโมงยังสามารถใช้ทำนายค่าอัปเดตจากไอโอดีนกัมมันตรังสีที่ 24 ชั่วโมงได้ด้วยโดยมีสมการความสัมพันธ์ดังนี้

$$\text{Estimated Iodine Uptake at 24hr} = 27.43 \cdot \ln(\text{Iodine Uptake at 3hr}) - 34.233 ; R^2 = 0.85$$

สรุป : ค่าอัปเดตจากเทคนิคซีเอ็มทีสามารถใช้ทำนายค่าอัปเดตด้วยไอโอดีนกัมมันตรังสีที่ 24 ชั่วโมงได้ แต่วิธีนี้จะขึ้นกับวิธีการคำนวณและการถ่ายภาพเก็บข้อมูล

คำสำคัญ : ไทรอยด์อัปเดต, ไอโอดีนกัมมันตรังสี, เทคนิคซีเอ็มทีเพอร์เทคนิคเดท, เวชศาสตร์นิวเคลียร์, ไฮเปอร์ไทรอยด์.

Hyperthyroidism develops when the body is exposed to excessive amount of thyroid hormone.⁽¹⁾ Hyperthyroidism is treated by three main methods: medication, radioactive iodine (RAI) therapy and surgery.⁽²⁾ All these three methods result in decreased production of the thyroid hormone from the thyroid gland.

Radioactive iodine uptake (RAIU) is the study of thyroid function which measures how much radioactive iodine is taken up by the thyroid gland in a certain period of time.⁽³⁾

Most centers of nuclear medicine in Thailand perform RAIU measurements at 3 and 24 hours to determine their therapeutic doses for hyperthyroidism patients treated by ¹³¹I. This is the conventional method to determine RAI doses.

Since 1970s, the radionuclide ^{99m}Tc-pertechnetate has been used for thyroid uptake studies and thyroid imaging.⁽⁴⁾ In some cases, the physician requests thyroid scan with ^{99m}Tc-pertechnetate for better treatment management, according to physical examination. Because the uptake of technetium by the thyroid reflects the state of the trapping function of the gland, it can be used in the study of thyroid physiology.⁽⁵⁾ Since ^{99m}Tc-pertechnetate is trapped by the thyroid gland in a manner and to a degree very similar to iodine, it may be used in both scanning and uptake measurements. Sometimes, RAIU was in conflict with clinical and laboratory examinations. The purpose of this study is to evaluate the thyroidal uptake by ^{99m}Tc-pertechnetate in relation to RAIU in the same patients. If RAIU shows false results from some reasons such as inaccuracy of the administration tracer dose, contamination in NaI solution, etc., this study may help

identify patients who have diagnostic discordance and RAIU for better management and treatment results. The thyroid uptake study by ^{99m}Tc-pertechnetate is not a routine procedure used for RAI treatment. If the thyroid uptake system is nonfunctioning, this method may be helpful in determining the therapeutic dose. Furthermore, thyroid uptake performed by ^{99m}Tc-pertechnetate takes 30 minutes, which is shorter than that performed by ¹³¹I for 2 days. So, this is an alternative method chosen for the convenience of the patient (e.g. patient come on Friday or from the upcountry, etc.).

Material and Method

The patients who request to perform RAIU were enrolled in this study. This prospective study was performed from June 2013 to December 2013 at the Division of Nuclear Medicine, King Chulalongkorn Memorial Hospital. This research proposal has been approved by the Institutional Review Board (IRB) of the Faculty of Medicine, Chulalongkorn University. The studies were performed on the same day after complete 24 hours RAIU measurement in hyperthyroidism patients (before RAI treatment). Siemens (SPECT) scintillation camera model ECAM with a low-energy, high-resolution, parallel-hole collimator was used. Images were obtained on a 256 X 256 matrix, zoom 3.2. Images were acquired with a dual energy window mode by preset 15 percent window width on photopeak of technetium and upper scatter peak. ^{99m}Tc-pertechnetate was administered intravenously in 100 – 150 MBq activity (2.7 - 4.05 mCi). Images of the ^{99m}Tc-pertechnetate syringe were obtained before and after injection at 30 cm distance from the detector to the syringe with a preset time of 1 minute; having

obtained the image on injection site to correct for the subcutaneous infiltration for 1 minute. The subjects were studied in supine position with their necks slightly hyperextended in the posture ordinarily used for thyroid uptake studied. Images for anterior thyroid at 5 minutes and 20 minutes after injection were acquired with a preset time of 5 minutes. Both anterior and oblique images were obtained as routine protocols.

Thyroid image was correct for scattering from ^{131}I by subtract thyroid image from scattering image. $^{99\text{m}}\text{Tc}$ - thyroid uptake was calculated with Siemens software on the basis of thyroid image as shown in Figure 1 (scattering correction) and syringe counts (correct for acquisition time, the decay of $^{99\text{m}}\text{Tc}$ and subcutaneous infiltration) as equation:

$$^{99\text{m}}\text{Tc} - \text{thyroid uptake} = \frac{\text{Net thyroid counts} \times 100\%}{(\text{Pre syringe counts} - \text{Post syringe counts})}$$

Statistical Analysis

The relationship between two variables represents graphically by a scatter diagram. Regression analysis generated an equation to describe the statistical relationship between predictor variable and response variable. The person product moment correlation (r) was used to measure the correlation between two variables. The t-test was used to analyze the statistically significant difference at 95% confidence. The probability, p value of less than 0.05 was considered to be statistically significant.

Results

The study consisted of 206 subjects, 150 women and 56 men, with the age ranging from 20 to 81 years (mean of 43.6 years). Twenty - four hours RAIU and number of subjects are shown in Table 1.

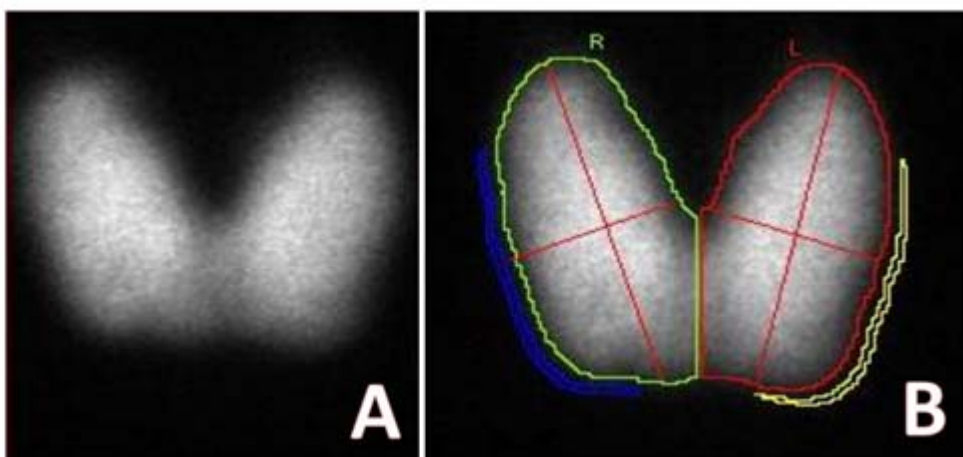


Figure 1. (A) Anterior view of thyroid scan image and (B) region of interest for right lobe, left lobe and background. Net thyroid counts were the sum of net right lobe and left lobe.

Table 1. Number of subjects and RAIU at 24hr.

24hr RAIU (%)	Number
<10	4
10 - 20	1
20 - 30	8
30 - 40	19
40 - 50	27
50 - 60	25
60 - 70	34
70 - 80	31
80 - 90	36
>90	21
Total	206

Table 2. ^{99m}Tc Thyroid scan and clinical diagnosis.

Scan diagnosis	Number
Thyroiditis	4
Graves disease	135
Graves + Cold Nodule	17
Graves + Hypo function	3
Toxic Adenoma	10
Nodular Goiter	3
Multi Nodular Goiter	20
Cold Nodule	3
Normal	11
Total	206

Thyroid scan was diagnosed by nuclear medicine physician and shown in Table 2.

The relationship between 24hr RAIU with ^{99m}Tc-uptake at 5 and 20 minutes was shown in Figure 2, 3 with correlation coefficient (r) of 0.862 (P < 0.001) and 0.842 (P < 0.001) accordingly. Estimated 24-hour iodine uptake base on 5 minutes

^{99m}Tc-uptake using the equation as: Estimated Iodine Uptake = 14.863 *ln (Per technetate Uptake at 5min) + 36.741 ; R² = 0.744. While estimated 24-hour iodine uptake base on 20 minutes ^{99m}Tc-uptake using the equation as: Estimated Iodine Uptake = 14.441*ln (Per technetate Uptake at 20min) + 34.314 ; R² = 0.708.

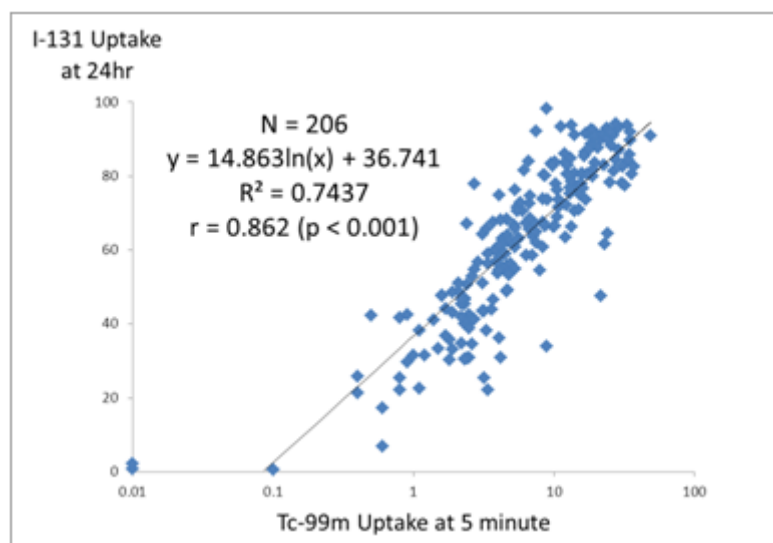


Figure 2. ^{99m}Tc-uptake at 5min versus RAIU at 24hr.

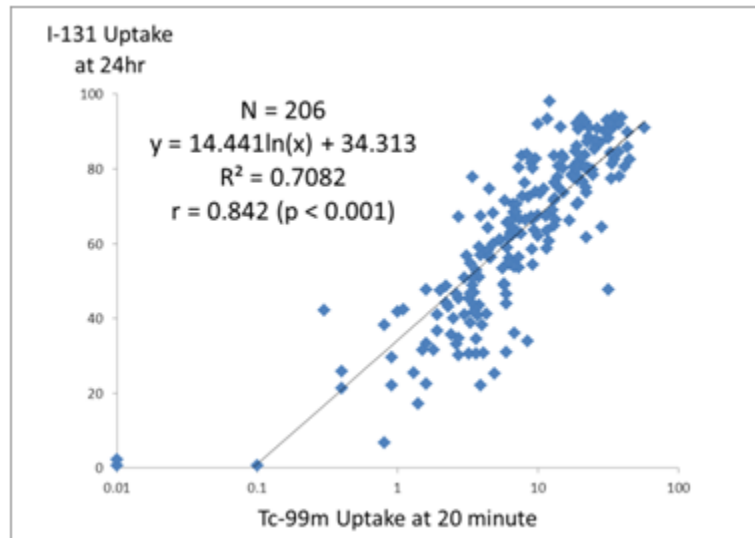


Figure 3. ^{99m}Tc -uptake at 20min versus RAIU at 24hr.

The relationship between RAIU at 3hr and 24hr was shown in Figure 4 with correlation coefficient (r) was 0.922 ($P < 0.001$). Estimated Iodine Uptake at 24hr = $27.43 \cdot \ln(\text{Iodine Uptake at 3hr}) - 34.233$; $R^2 = 0.85$

^{99m}Tc -uptakes at 20 minutes were mostly higher than uptakes at 5 minutes. The relationship between ^{99m}Tc -uptake at 5 and 20 minutes was shown in Figure 5 with correlation coefficient (r) was 0.984 ($P < 0.001$). Estimated ^{99m}Tc -uptake at 20min = $1.163 \cdot ^{99m}\text{Tc}$ -uptake at 5min + 0.585; $R^2 = 0.968$.

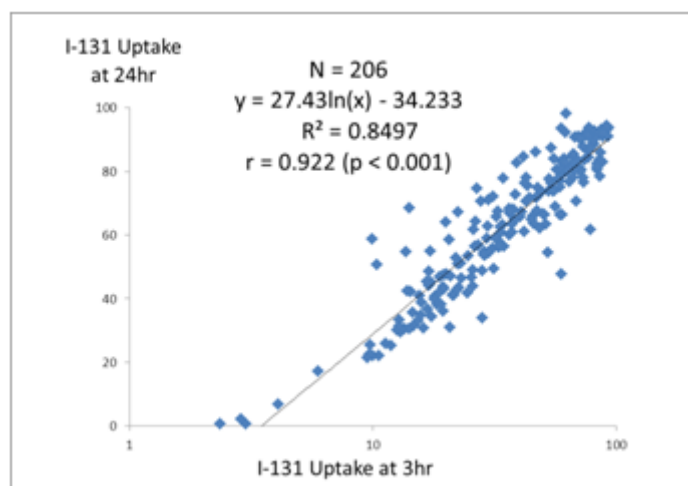


Figure 4. RAIU at 3hr versus 24hr.

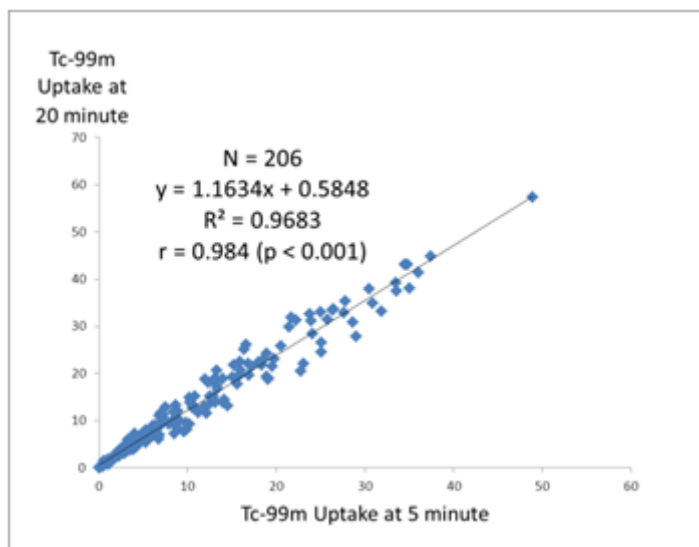


Figure 5. ^{99m}Tc-uptake at 5min versus 20min.

Discussion

^{99m}Tc energy had not been interfered for iodine window but ¹³¹I energy was interfered by ^{99m}Tc window as shown in Figure 6. Scatter peak from iodine is nearly symmetry between photopeak window and upper scatter window.

In this study, we performed RAIU first. So, its have some scatter from iodine to interfere thyroid uptake with ^{99m}Tc-pertechnetate. This problem had been corrected by subtract image of upper scatter window from photopeak window as shown in Figure 7.

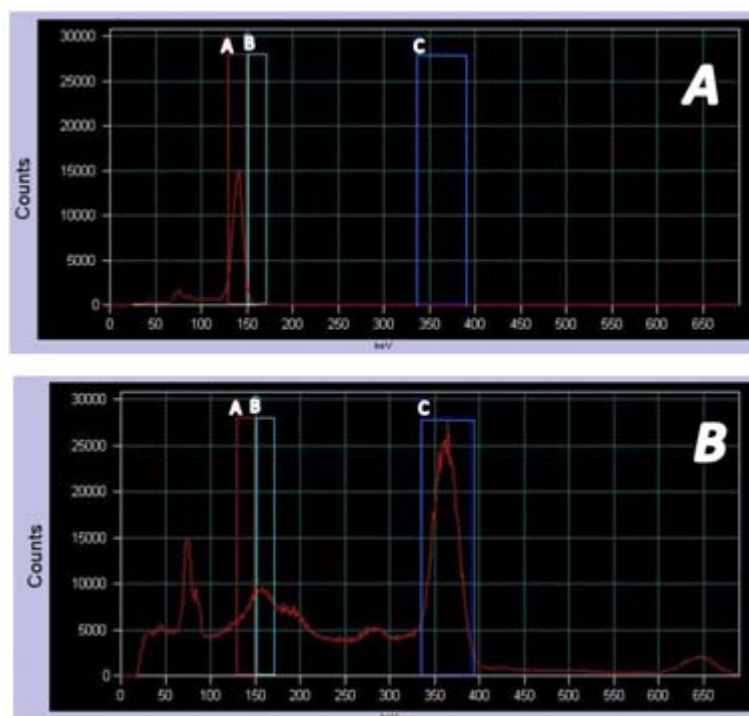


Figure 6. (A) ^{99m}Tc spectrum and (B) ¹³¹I spectrum on LEHR collimator with triple energy window; Technetium window (A), Upper scatter window for Technetium (B) and Iodine window (C).

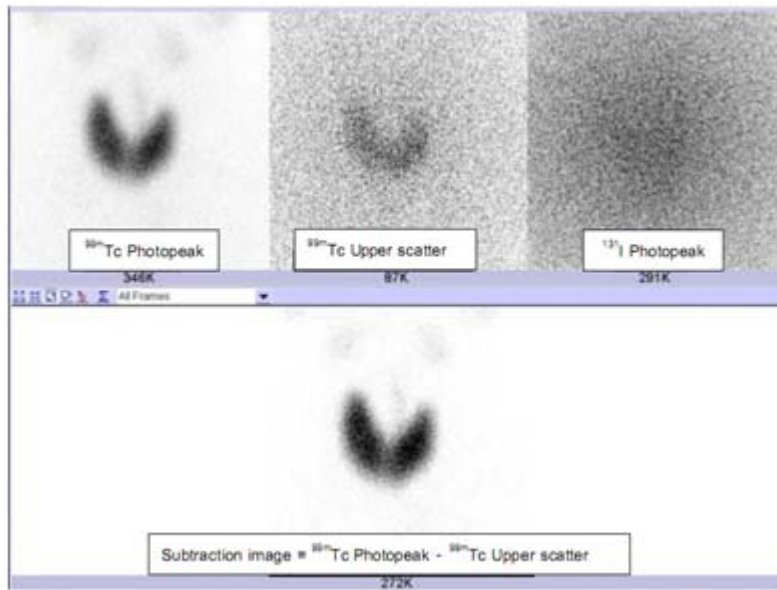


Figure 7. (Upper row) Thyroid scan images with triple energy window for ^{99m}Tc -photopeak, upper scatter and ^{131}I -photopeak, (Lower row) subtraction image for scatter correction.

RAI therapy for hyperthyroidism, RAIU at 3hr is so important to detect early uptake especially in case of rapid turnover and RAIU at 24hr is needed to determine therapeutic dose. RAIU at 24hr variation in 10% does not change therapeutic planning. ^{99m}Tc -uptake can help physicians in both diagnosis and treatment. If the physician suspects thyroid nodule, thyroid scan can be performed. ^{99m}Tc -uptake is related to iodine uptake, but iodine uptake is more reliable due to physiological process in thyroid gland. In case of patients who are not available for 24hr RAIU, ^{99m}Tc -uptake is helpful to estimate 24hr RAIU and compare the result with estimation from 3hr RAIU. This will make confident in treatment. In case of suspicion of RAIU error, ^{99m}Tc -uptake can confirm the result without repeating the examination. These will help the patient to receive treatment by RAI immediately. ^{99m}Tc -uptake takes a short time in examination than RAIU. Estimated equation based on ^{99m}Tc -uptake at 5 minute

($r = 0.862$) shows better correlation than ^{99m}Tc -uptake at 20 minutes ($r = 0.842$). This is an alternative method for the treatment of hyperthyroidism with RAI.

Although the correct therapeutic dose was calculated for each patient, not every treatment would be successful to correct hyperthyroidism, particularly if the thyroid goiter is quite large; a second dose is occasionally needed.

^{99m}Tc -uptake by this method depends on acquisition and calculation technique. Each imaging system may have different scatter spectrum due to the collimator used, pulse height analyzer (PHA) capability to open more than one window and window width setting, method for decay time and leakage corrections were included. So, each center should perform and find estimated equation suitable for the particular parameters to obtain high accuracy and benefits to the thyroid patients.

Conclusion

^{99m}Tc -pertechnetate uptake can be used to estimate 24hr iodine uptake. ^{99m}Tc -uptake at 5 minutes gives better prediction than ^{99m}Tc -uptake at 20 minutes. RAIU at 3hr is still needed to determine the early uptake. This is an alternative method to determine RAI therapeutic dose because of the short time to perform from two days to one day. This method also depends on the acquisition and calculation techniques.

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