Utility of Intraoperative Radioguided Hand-Held Gamma Probe to Detect Hyperplastic Parathyroid Glands in Renal-Induced Hyperparathyroidism Patients

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Background: *Radioguidance has high sensitivity and specificity to detect single parathyroid gland disease, especially adenomatous gland. In multiglandular disease, the ability to detect the glands is still unclear.*
Objective: *To investigate the utility of intraoperative ^{99m}Tc-sestamibi radioguidance (hand-held gamma probe) for diagnosis and detection of cervical hyperplastic parathyroid glands in renal-induced hyperparathyroidism patients.*
Material and Method: *A prospective analytical study was conducted between March 2014 and March 2015. Thirty-three end stage renal failure patients were included in the present study. All patients were intravenously administered ^{99m}Tc-sestamibi prior to surgery and underwent bilateral neck exploration. After suspected parathyroid tissues were identified, the hand-held gamma probe was used to quantify the surgical area, which was reported as four values, thyroid counts, in vivo counts of suspected tissue, ex vivo counts of suspected tissue, and surgical bed counts. The first interesting parameter (criterion 1) is the radioactivity ratio, which was calculated as a function of ex vivo radioactivity versus surgical bed radioactivity and expressed as a simple percentage. The second interesting parameter (criterion 2) is the differences between in vivo radioactivity and thyroid radioactivity. All specimens were sent for pathological study as a gold standard for diagnosis. The experimental protocol was approved by the Ethical Committee of Rajavithi Hospital (No. 041/2557).*
Results: *One hundred twenty nine specimens were excised of which 119 were hyperplastic parathyroid glands. The means of the radioactivity from in vivo hyperplastic parathyroid tissues were significantly higher than those in non-parathyroid tissues (1,133.29 cps vs. 688.30 cps, p = 0.001). The means of the radioactivity from ex vivo hyperplastic parathyroid tissues were significantly higher than those in non-parathyroid tissues (469.11 cps vs. 167.10 cps, p = 0.003 respectively). The sensitivity, specificity, and the accuracy for predicting hyperplastic parathyroid tissue by using a 20% cut-off point of radioactivity ratio (criterion 1) were 95.00%, 70.00%, and 93.00% respectively. The area under the curve from the ROC curve was 0.83 (95% CI = 0.65, 1.00). The sensitivity, specificity, and accuracy for predicting hyperplastic parathyroid tissue by using greater than 100 cps gap of the difference between in vivo radioactivity and thyroid radioactivity (criterion 2) were 81.70%, 60.00%, and 80.00% respectively. The area under the curve from the ROC curve was 0.81 (95% CI = 0.69, 0.92). Using the parallel calculation method, the sensitivity increased to 98.30%. Using the serial calculation method, the specificity increased to 80.00% for prediction.*
Conclusion: *The hand-held gamma probe can be used to identify hyperplastic parathyroid glands with high sensitivity by using criteria 1. Moreover, the researcher believes that the other radioactivity calculation (criterion 2) is a quick and helpful tool for screening intraoperative questionable lesions. Finally, the results show that the probe's sensitivity can be enhanced by using parallel method calculation between the two criteria and its specificity can be enhanced by using serial method calculation.*

Keywords: *Hand-held gamma probe, Radioguided parathyroid surgery, Parathyroidectomy, Renal-induced hyperparathyroidism*

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Hyperparathyroidism (HPT) is a physiologic disease based on hyperfunction with attendant parathyroid hormone overproduction within one or more of the parathyroid glands[1]. HPT is a common complication of the chronic renal failure (CRF). The Canadian study[2] found that the incidence of parathyroidectomy in these patients was 11.4 per 1,000 person-year before the cinacalcet era. After cinacalcet became available, the incidence was reduced to 3.6 per 1,000 person-year[2]. In Thailand, cinacalcet is not available for most CRF patients. As a result, if they failed to respond to available medical treatments, they are treated by surgery.

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The types of surgery performed has been variable; subtotal parathyroidectomy (sTTPD), total parathyroidectomy with (TTPDw) or without (TTPDs) autotransplantation. TTPDs may not suitable for patients who will receive a kidney transplantation because the control of serum calcium levels may be difficult after kidney transplantation[3,4]. Currently, sTTPD and TTPDw are the standard surgical procedures for renal-induced HPT. In both of these operations, a small piece of parathyroid gland will be retained in the patient, but in a different location. sTTPD is the procedure which leaves a small piece of the most normal-looking gland tissue in the neck, but in TTPDw it is left in another part of the patient's body, such as a muscle in the forearm or thigh. Because of the different transplant location, sTTPD may have more complications resulting in the need for reoperation than TTPDw in the case of recurrence or recalcitrant HPT[5-8].

In renal-induced HPT, the rate of persistent or recurrent disease is around 3 to 12% after initial surgical treatment. The failure is often related to incomplete identification of all parathyroid glands[9-11]. Normally, preoperative or intraoperative localization studies are not routinely performed for many reasons, such as poor diagnostic performance[12]. Recently, some surgeons advocated the use of an intraoperative radioguided technique for patients with renal-induced HPT. Some studies have showed that radioguidance can reduce operative time, length of hospital stay, and the need for frozen sections[8,13]. Many studies have reported the ability of intraoperative radioguided to locate adenomatous glands in primary HPT, as well as supernumerary and ectopic glands, resulting in a decreased risk of persistent or recurrent disease[11,14-16]. Few articles have demonstrated the benefit and diagnostic performance of intraoperative radio-guidance or gamma probe in multiglandular disease liked renal-induced HPT[9,13,17].

The aim of the present study was to evaluate the diagnostic utility of intraoperative radioguidance (hand-held gamma probe for detection of ^{99m}Tc sestamibi) in renal-induced HPT patients.

Material and Method

Patient selection

This prospective study protocol was approved by the Ethical Committee of Rajavithi Hospital (No. 041/2557). Between March 2014 and March 2015, the data were collected from 43 HPT patients. Only 33 patients met the inclusion criteria and were enrolled in the present study. The inclusion criteria were patients who had been diagnosed with HPT related to end-stage renal failure and aged 18 years or more. They were referred from a nephrologist on the basis that their HPT had been unsuccessfully controlled by low-phosphate diet restriction and medical treatment: calcium acetate or calcium carbonate and aluminum or magnesium salt. Ten subjects were excluded because of primary HPT (7 subjects) and recurrent HPT after previous parathyroid surgery (3 subjects).

Surgical method

All patients were intravenously administrated 0.3 to 0.4 mCi per kilogram of ^{99m}Tc-sestamibi for 45 to 60 minutes prior to making the incision. All patients underwent bilateral neck exploration under general anesthesia by five experienced otolaryngologists who were well-trained in the use of the intraoperative hand-held gamma probe, which was applied within three hours of injection (Fig. 1).

Normally, surgeons tried to explore all of four sites of suspected parathyroid tissue within each quadrant of the neck by using their knowledge of anatomy. After they found the suspected parathyroid tissues, the radioactivity was quantified in counts per second of gamma rays using a 15 mm collimated gamma probe and control unit SG04 ("Crystal Wireless Probe", Crystal Photonics GmbH, Berlin, Germany; Fig. 2) using the following steps:

Step 1: The gamma probe was placed over the thyroid gland in that quadrant of the neck and

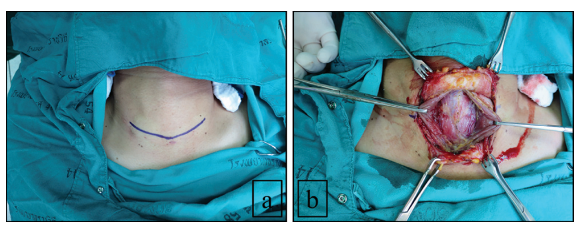

Fig. 1 Collar incision (a) and bilateral neck exploration (b).

Fig. 2 Collimated Crystal Wireless Gamma Probe: 15 mm diameter sensor tip probe (a), and control unit SG 04 (b).

the count was recorded as "thyroid radioactivity" (Fig. 3a).

Step 2: The radiation from the suspected parathyroid tissue in that quadrant was recorded before it was removed. This second count was the "in vivo count" (Fig. 3b, c).

Step 3: The excised tissue was scanned away from the operating table (around 6 feet). This third count was the "ex vivo count" (Fig. 3d).

Step 4: The bed of the excised area in that quadrant was scanned to produce the forth count, referred to as the "surgical bed count" (Fig. 3e).

These four steps were performed repeatedly until results had been recorded from all of four quadrants. In the case of incomplete identification of four areas of suspected parathyroid tissue in the primary survey, the hand-held gamma probe was used to identify the tissues in other areas. In the case of complete identification of four sets of parathyroid tissue, the most normal-appearing tissue was partially cut and diced, then the auto-transplantation was done into an intramuscular pocket in the anterolateral thigh area and its location was marked with a Liga clip. At the end of the operations, all excised tissues were sent for pathological study.

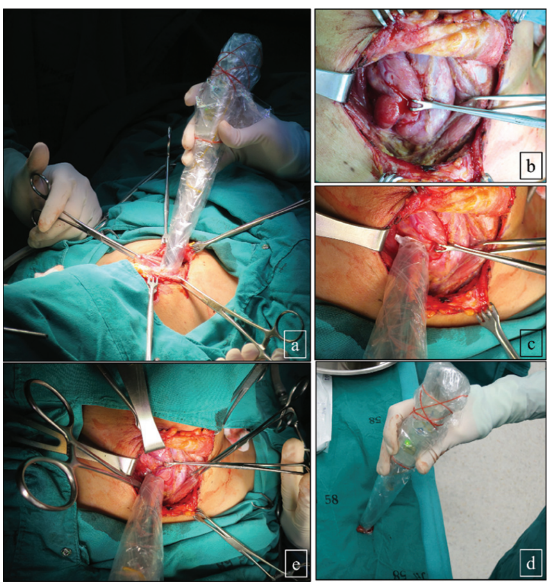

Fig. 3 Measurement the radioactivity: counting on the thyroid gland (a), suspected right parathyroid tissue (b), counting on the suspected tissue (c), counting on the suspected tissue outside the patient's neck (d), and counting on the surgical bed after removing the suspected tissue (e).

Data analysis

All analyses were performed using the statistical program SPSS (version 17.0, SPSS Inc., Chicago, IL). Data were presented as mean ± standard deviation (SD), range (minimum to maximum) for continuous variables and number (%) for categorical variables. The differences between group means were analyzed using the Student's t-test. A Receiver Operator Characteristic (ROC) curve was generated by plotting the sensitivity against 1-specificity, and the area under the curve with 95% confidence intervals (95% CI) were calculated. The optimal cut-off points for screening by gamma probe were selected based on the ROC curve analysis. Sensitivity, specificity, positive predictive values (PPV), and negative predictive values (NPV) were calculated using a 2x2 table of the collected data. A p-value less than 0.05 was considered statistical significance.

Results

Thirty-three renal failure patients were included in the study. Of these patients, 17 were males (51.5%) and the mean age (± SD) of the group was 44.61 (±12.04) years. There were 17 secondary HPT patients (51.5%) and 16 tertiary HPT patients (48.5%). The mean duration of hemodialysis was 8.39±5.18 years. The averages of preoperative blood tests were shown in Table 1.

One hundred twenty nine specimens were obtained from the 33 patients. Pathological studies (gold standard) revealed that 119 specimens were hyperplastic parathyroid glands, five specimens were fat tissues, three specimens were hyperplastic lymph nodes, one was thymus tissue, and one was benign thyroid tissue. Of the 119 hyperplastic parathyroid glands, the intraoperative finding was four glands in 24 patients, only three glands in six patients, two glands in two patients, and one gland in one patient. A summary of the mean radioactivity level was shown in Table 2.

In the group of hyperplastic parathyroid tissue, the averages of radioactivity on thyroid gland, in vivo and ex vivo situations were 788.49±210.26, 1,133.29±398.69, and 469.11±305.50 cps, respectively, which is significantly higher than those in the non-parathyroid tissue group (p-value = 0.031, 0.001, and 0.003) (Table 2).

In the present study, the author decided to use the ratio of radioactivity (criterion 1) and the differences in radioactivity (criterion 2) for intraoperatively diagnosing the suspected tissue as hyperplastic parathyroid gland. The radioactivity ratio was calculated as a function of the ex vivo tissue radioactivity versus the surgical bed radioactivity and expressed as a simple percentage. The differences between in vivo radioactivity and thyroid radioactivity were calculated and were shown in Table 3.

The radioactivity ratio and the differences were used to calculate the diagnostic performance of the technique using a 2x2 table and a ROC curve was created as shown in Fig. 4. From this calculation, the statistical analysis revealed that the most appropriate cut off point for criterion 1 was 20%, which gave 95.0% sensitivity, 70.0% specificity, 93.0% accuracy, 97.4% PPV, and 53.8% NPV. In the case of criterion 2, the most appropriate cut off point was 100 cps, which gave 81.7% sensitivity, 60.0% specificity, 80.0% accuracy, 95.9% PPV, and 22.2% NPV (Table 4). Moreover, the researcher has examined the diagnostic performances based on serial and parallel methods using criterion 1 and 2, the results of which were shown in Table 4. The serial method gave higher specificity but lower sensitivity, while the parallel method gave higher sensitivity without changing of specificity (Table 4).

Table 1. Baseline characteristics (n = 33 cases)

	2° HPT (n = 17)	3° HPT (n = 16)	Total (n = 33)
Sex			
Male	8	9	17 (51.5%)
Female	9	7	16 (48.5%)
Age (years)	45.24±11.42	43.94±13.02	44.61±12.04
Duration of HD (years)	8.82±4.20	7.94±6.17	8.39±5.18
iPTH (pg/ml)	1,574.29±693.82	2,032.56±782.25	1,796.48±762.64
Ca (mg/dL)	10.60±0.80	11.08±0.84	10.83±0.85
PO4 (mg/dL)	5.73±1.37	6.53±2.08	6.12±1.77
ALP (U/L)	386.31±439.93	331.36±201.38	360.67±345.05
Vit. D (ng/ml)	30.62±10.52	31.07±13.00	30.84±11.57
GFR (ml/minute/1.73m^2)	7.29±3.31	8.38±8.05	7.82±6.01

2° HPT = secondary hyperparathyroidism; 3° HPT = tertiary hyperparathyroidism; HD = hemodialysis; iPTH = intact parathyroid hormone; Ca = serum calcium level; PO4 = serum phosphate level; ALP = serum alkaline phosphatase; Vit. D = serum vitamin D level; GFR = glomerular filtration rate

Data were presented as mean ± standard deviation and number (%)

Table 2. Radioactivity data of all specimens (n = 129)

	PTG (n = 119)	Non PTG (n = 10)	95% CI of mean difference	*p*-value
Thyroid	788.49±210.26 (312 to 1,346)	637.10±209.48 (312 to 925)	14.21, 288.58	0.031
In vivo	1,133.29±398.69 (133 to 2,194)	688.30±215.01 (447 to 1,083)	191.85, 698.13	0.001
Ex vivo	469.11±305.50 (92 to 1,423)	167.10±241.40 (2 to 720)	105.64, 498.38	0.003
Surgical bed	734.41±285.64 (127 to 1,600)	670.20±255.05 (380 to 1,137)	-120.54, 248.97	0.493

Non PTG = non-parathyroid tissues; PTG = parathyroid tissues

Radioactivity values were measured in counts per second (CPS) and presented as mean ± standard deviation (min to max)

Table 3. Comparison the mean of radioactivity ratio and the mean of the radioactivity differences between non-parathyroid tissues and hyperplastic parathyroid glands

	PTG (n = 119)	Non PTG (n = 10)	95% CI of mean difference	*p*-value
Criteria 1	77.90±112.45 (16.27 to 1,116.54)	22.50±31.89 (0.43 to 84.71)	-15.44, 126.23	0.124
Criteria 2	357.27±326.03 (-807 to 1,481)	51.20±214.70 (-236 to 370)	97.75, 514.38	0.004

Non PTG = non-parathyroid tissues; PTG = parathyroid tissues

Criterion 1 = (ex vivo counts / surgical bed counts) x 100, the means are presented in percent

Criterion 2 = in vivo counts – thyroid radioactivity, the means were measured in counts per second (CPS)

The row for “criterion 2”, there was less than 4.0% missing data in the column of parathyroid tissues (n = 115, missing samples = 4)

The values were presented as mean ± standard deviation (min to max)

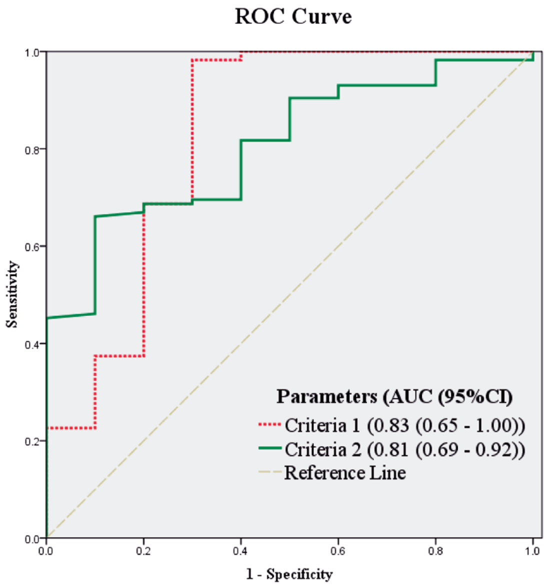

Fig. 4 ROC curve and area under the curve (AUC) for criteria 1 and 2 for evaluation of sensitivity, specificity, and the cut off point for screening hyperplastic parathyroid tissues.

Discussion

Because of medical innovation, the average life expectancy of end-stage renal disease (ESRD) patients has been extended. Secondary and tertiary HPT are frequent complications of long-term dialysis treatment. In spite of new medical treatments, such as cinacalcet which has been widely used for chemical parathyroidectomy(18). However, this treatment is not widely available in many countries such as Thailand. As the interest in parathyroid surgery for ESRD patients has been increasing, various attempts have been made to identify modern techniques to reduce the failure of treatment.

Some radioisotopes are preferentially retained in mitochondria-rich cells, so the radioactivity in suspected hyperplastic parathyroid tissue in the present study were significant high. In the past, many surgeons had used this knowledge to identify adenomatous parathyroid glands in primary HPT. In December 1999, Murphy and Norman postulated "the 20% rule" for intraoperative evaluation of hyperfunctional parathyroid tissue by using radioguidance in primary HPT patients, in whom the most common pathophysiology of the hyperfunctional tissue was a single adenoma. In the case of secondary or tertiary HPT with multiple gland hyperfunction, intraoperative radioguidance studies were scant(1). In 2003, Chen et al(14) reported their study which determined the utility of radioguided parathyroidectomy for patients with HPT, including secondary and tertiary HPT patients. They used the 20% rule described by Murphy and Norman(1) as the cut-off point for identifying hyperplastic glands. The results indicated that "the 20% rule" can be applied to parathyroid adenomas and to hyperplastic glands(17,19).

Table 4. Comparison of sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy between "the criterion 1" and "the criterion 2"

	Intraoperative finding and pathological studies		Sensitivity (%)	Specificity (%)	Accuracy (%)	PPV (%)	NPV (%)
	Hyperplastic PTG	Non PTG					
Criterion 1							
Positive (≥20%)	113	3	95.00	70.00	93.00	97.40	53.80
Negative (<20%)	6	7					
Criterion 2							
Positive (≥100)	94	4	81.70	60.00	80.00	95.90	22.20
Negative (<100)	21	6					
Criterion 1 and 2 (serial method)							
Positive	91	2	79.10	80.00	79.20	97.80	25.00
Negative	24	8					
Criterion 1 or 2 (parallel method)							
Positive	116	2	98.30	71.40	96.80	98.30	71.40
Negative	2	5					

Non PTG = non-parathyroid tissues; PTG = parathyroid tissues
Criterion 1 = (ex vivo counts / surgical bed counts) x 100, the means were presented in percent
Criterion 2 = in vivo counts – thyroid radioactivity, the means were measured in counts per second (CPS)
The row for "criterion 2", there was fewer than 4.0% missing data in the column of parathyroid tissues (n = 115, missing tissues = 4)

Nevertheless, the sample size calculation was not clear in that study and negative controls were not included.

In the present study, the researcher used the radioactivity function quantified from hand-held gamma probe by two criteria, the ratio between ex vivo counts and surgical bed counts (as "criterion 1") and the differences between ex vivo counts and thyroid radioactivity (as "criterion 2"). This approach has not been used in renal-induced HPT previously. The cut-off point for the isolated criterion was computed using an ROC curve. The curve showed the appropriate sensitivity (95.00%) and specificity (70.00%) to determine hyperfunctional glands using the ratio 20% as in Murphy and Norman's study[1]. Moreover, the present study postulated criterion 2, which is based on the fact that after removing the radioactivity of background (thyroid radioactivity), the remaining high radioactivity should indicate hyperfunctional parathyroid glands. The ROC curve for this criterion showed that the cut-off point for the difference should be more than 100 cps. The advantage of the criterion 1 is that it has a high sensitivity for detection of hyperplastic parathyroid tissue but it does not have a high specificity and its use may result in time wasting because the ratios will be calculated after the surgeon already excised the suspected tissue. In the case of criterion 2, the calculation is easy to perform before excision, but this criterion has a lower sensitivity and specificity than the criterion 1.

In addition to this, two other statistical methods were used to identify suspected hyper-functional parathyroid tissue. The first method, the serial method, is based on positive agreement between criterion 1 and 2. The other method is called the parallel method. The parallel method is based on the inclusion of the positive results from criterion 1 or criterion 2. In the serial method, the hand-held gamma probe will provide higher specificity but lower sensitivity in identifying hyperplastic glands, while the parallel method enhances the sensitivity without reducing the specificity.

Using the hand-held gamma probe in intraoperative tumor localization provides the surgeon with instantaneous navigational feedback for optimizing the identification of all possible sites of disease, and may ultimately impact favorably on long-term patient outcomes. However, in the present study, there were failures to detect all four hyperplastic glands in 27.27% of cases (9 in 33 patients).

Conclusion

The present study showed the radioguided surgery is a sensitive adjunct for the intraoperative localization of hyperplastic parathyroid glands. Under 0.3 to 0.4 mCi per kilogram of intravenously ^{99m}Tc-sestamibi, the hand-held gamma probe can identify the hyperplastic parathyroid glands with 95.00% sensitivity when using greater than the 20% cut-off point of the ratios between ex vivo count and Surgical bed counts. With regard to the differences between in vivo counts and thyroid radioactivity, a gap of more than 100 cps can be used as another parameter for identifying hyperplastic parathyroid glands with 81.70% sensitivity. In the future, the researcher believes that this combined approach has the potential to greatly reduce incomplete removal of parathyroid tissue at primary surgery and to improve long-term outcomes. However, this screening tool cannot be used as a substitute for pathological studies.

What is already known on this topic?

The thyroid and parathyroid glands are mitochondria-rich organs which readily take up radio-pharmaceuticals. The washout of these agents from hyperfunctional parathyroid glands is slower than from thyroid glands. Many surgeons have used this principle for intraoperative localization of pathological glands in single gland disease, like adenoma. Murphy and Norman[1] had determined that parathyroid adenomas contain radioactivity of at least 18% of that in the bed of the surgical field, and had established "the 20% rule" for adenomatous lesions.

What this study adds?

The present study showed that not only the adenomatous parathyroid glands have high radioactivity but also the hyperplastic lesions, and confirmed that "the 20% rule" can be used for intraoperative screening of hyperplastic lesions with high sensitivity. Furthermore, the author had reported other criteria using statistical methods for screening of suspected lesions.

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Potential conflicts of interest

None.

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การหาความสามารถในการตรวจวินิจฉัยและตรวจจับต่อมพาราไทรอยด์ที่ผิดปกติชนิดไฮเปอร์พลาเซียจากผู้ป่วยโรคไตวายเรื้อรังระยะสุดท้าย โดยใช้การตรวจจับรังสีแกมมาจากสารเภสัชรังสี ^{99m}Tc-MIBI ด้วยหัวตรวจจับรังสีแกมมาขนาดเล็กในขณะผ่าตัดต่อมพาราไทรอยด์

พรเอก อภิพันธุ์

วัตถุประสงค์: *เพื่อศึกษาสมรรถภาพของหัวตรวจจับรังสีแกมมาขนาดพกพา ในการตรวจวินิจฉัยรังสีแกมมาซึ่งแผ่จากสารเภสัชรังสี ^{99m}Tc-MIBI ของต่อมพาราไทรอยด์ที่มีพยาธิสภาพชนิดไฮเปอร์พลาเซีย ในระหว่างผ่าตัดต่อมพาราไทรอยด์ ในผู้ป่วยภาวะฮอร์โมนพาราไทรอยด์สูงเนื่องจากภาวะไตวายเหนี่ยวนำ*

วัสดุและวิธีการ: *เป็นการศึกษาไปข้างหน้าเชิงวิเคราะห์ โดยเก็บข้อมูลในช่วงเวลาตั้งแต่ เดือนมีนาคม พ.ศ. 2557 ถึง มีนาคม พ.ศ. 2558 ผู้ป่วยโรคไตวายเรื้อรังที่มีภาวะฮอร์โมนพาราไทรอยด์สูง อยู่ในเกณฑ์คัดเข้าทั้งหมด 33 ราย ทุกรายรับการฉีดสารเภสัชรังสี ^{99m}Tc-MIBI ก่อนการผ่าตัดประมาณ 45-60 นาที และรับการผ่าตัดโดยเปิดเนื้อเยื่อช่องคอเพื่อสำรวจหาต่อมพาราไทรอยด์ตามหลักกายวิภาค วัดปริมาณรังสีแกมมาที่แผ่มาจากเนื้อเยื่อที่ได้จากการค้นหาเบื้องต้นก่อนตัดก้อนออก (in vivo counts) หลังตัดก้อนออก (ex vivo counts) เนื้อต่อมไทรอยด์ (thyroid radioactivity) และพื้นคอหลังจากเอาเนื้อเยื่อที่สงสัยออก (surgical bed counts) บันทึกปริมาณรังสีแกมมาของเนื้อเยื่อทุกชนิดในหน่วย counts per second นำชิ้นเนื้อทุกชิ้นส่งตรวจพยาธิวิทยาเพื่อเป็นการวินิจฉัยที่สุด นำผลปริมาณรังสีที่ได้มาทำการคำนวณทางสถิติ*

ผลการศึกษา: *จากการผ่าตัดได้ชิ้นเนื้อทั้งหมด 129 ชิ้น จากผู้ป่วยโรคไตวายเรื้อรังที่มีข้อบ่งชี้ในการรักษาด้วยการผ่าตัด 33 ราย โดยเป็นต่อมพาราไทรอยด์ชนิดไฮเปอร์พลาเซียจากผลพยาธิวิทยา 119 ชิ้น จากการรวบรวมข้อมูลปริมาณรังสีแกมมาที่วัดได้จากเนื้อเยื่อที่สงสัยก่อนตัดออกจากคอพบว่า ชิ้นเนื้อที่ทราบวินิจฉัยภายหลังว่าเป็นต่อมพาราไทรอยด์ชนิดไฮเปอร์พลาเซียมีปริมาณรังสีโดยเฉลี่ยสูงกว่าชิ้นเนื้อที่ไม่ใช่ต่อมพาราไทรอยด์อย่างมีนัยสำคัญทางสถิติ (1133.29 กับ 688, p-value = 0.001) สอดคล้องกับปริมาณรังสีแกมมาของชิ้นเนื้อภายหลังตัดออกจากคอของผู้ป่วย โดยปริมาณรังสีแกมมาโดยเฉลี่ยของชิ้นเนื้อที่เป็นต่อมพาราไทรอยด์ชนิดไฮเปอร์พลาเซียมีค่าสูงกว่าชิ้นเนื้อที่ไม่ใช่ต่อมพาราไทรอยด์อย่างมีนัยสำคัญทางสถิติเช่นกัน (469.11 กับ 167.10, p-value = 0.003) ถ้าใช้สัดส่วนปริมาณรังสีแกมมาภายนอกร่างกายต่อปริมาณรังสีแกมมาที่เนื้อเยื้อพื้นคอหลังจากเอาชิ้นเนื้อที่สงสัยออก มาเป็นหนึ่งในข้อกำหนดเพื่อวินิจฉัยต่อมพาราไทรอยด์ชนิดไฮเปอร์พลาเซีย พบว่าการใช้จุดตัดที่สัดส่วนมากกว่า 20% ส่งผลให้การใช้หัวตรวจจับรังสีแกมมาขนาดพกพาให้ความไวในการวินิจฉัยชิ้นเนื้อที่สงสัย 95.00% ความจำเพาะต่อการวินิจฉัย 70.00% และความถูกต้องแม่นยำในการวินิจฉัย 93.00% โดยพื้นที่ใต้ ROC curve ของข้อกำหนดนี้เท่ากับ 0.83 (95% CI = 0.65, 1.00) ในข้อกำหนดที่สอง ใช้ผลต่างของปริมาณรังสีแกมมาของชิ้นเนื้อที่สงสัยก่อนทำการตัดออกกับปริมาณรังสีแกมมาจากต่อมไทรอยด์พบว่าถ้าชิ้นเนื้อที่สงสัยมีปริมาณรังสีแกมมามากกว่าต่อมไทรอยด์เกินกว่า 100 cps จะสามารถวินิจฉัยชิ้นเนื้อที่สงสัยได้โดยให้ความไว 81.70% ความจำเพาะ 60.00% และความถูกต้องแม่นยำ 80.00% โดยพื้นที่ใต้ ROC curve ของข้อกำหนดนี้เท่ากับ 0.81 (95% CI = 0.69, 0.92) นอกจากนี้เมื่อนำข้อกำหนดที่ 1 และ 2 มาทดสอบซ้ำด้วยวิธีคู่ขนาน กล่าวคือถ้าข้อกำหนดข้อใดข้อหนึ่งให้ผลบวก ถือว่าการวินิจฉัยรวมนั้นให้ผลบวก พบว่าสามารถเพิ่มความไวในการวินิจฉัยได้ถึง 98.30% ในทางกลับกันถ้าพิจารณาโดยข้อกำหนดทั้งสองต้องให้ผลบวกพร้อมกัน (พิจารณาตามลำดับ) จะสามารถเพิ่มความจำเพาะในการวินิจฉัยชิ้นเนื้อนั้น ๆ ได้ถึง 80.00%*

สรุป: *การตรวจชิ้นเนื้อในระหว่างการผ่าตัดต่อมพาราไทรอยด์ ด้วยการใช้หัวตรวจจับรังสีแกมมาขนาดพกพาเข้าช่วยในการคัดกรองหาต่อมพาราไทรอยด์ชนิดไฮเปอร์พลาเซียมีความไวและความแม่นยำสูง โดยมีหลากหลายการคำนวณให้เลือกใช้ให้เข้ากับวัตถุประสงค์ของการผ่าตัดนำชิ้นเนื้อที่มีพยาธิสภาพออกไป จึงเป็นประโยชน์ช่วยชี้นำสำหรับ โสต ศอ นาสิกแพทย์ และ ศัลยแพทย์ ในการผ่าตัดนำต่อมพาราไทรอยด์ออกในผู้ป่วยที่มีภาวะฮอร์โมนสูงจากภาวะไตวายเรื้อรังเหนี่ยวนำ อย่างไรก็ตามเครื่องมือนี้ไม่สามารถนำมาทดแทนการวินิจฉัยโดยการตรวจทางพยาธิวิทยาได้*