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Graphical analysis of ^{99m}Tc thyroid scintigraphy

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A new non-invasive simple method for quantitative evaluation of thyroid was presented using graphical analysis of the transfer process of technetium-99m pertechnetate (^{99m}Tc) from the blood to thyroid. Thirty subjects were studied. After a bolus injection of 111 MBq of ^{99m}Tc, the data were recorded on a 128 × 128 matrix as 60 frames of 1.5-second duration. ROIs were placed over the aortic arch and bilateral thyroid lobes. The activity of the aorta was monitored instead of the arterial activity. Graphical analysis by plotting $B(t)/A(t)$ versus $\int_0^t A(\tau)d\tau/A(t)$ gave a straight line within the first 30 seconds in all subjects. The slope of the line was the unidirectional influx rate of ^{99m}Tc (k_u). Thyroid perfusion index (TPI) was calculated to standardize where the ratio of $ROI_{thyroid}$ size to ROI_{aorta} size was set as 10. K_u and TPI showed good correlation with ^{99m}Tc thyroid uptake. Hyperthyroid patients showed high values of k_u and TPI. Considering that these indices were determined at the first pass of ^{99m}Tc, this method may be helpful especially in the evaluation of thyroid perfusion.

Key words: graphical analysis, Patlak plot, thyroid, technetium-99m pertechnetate, scintigraphy

INTRODUCTION

FOR the evaluation of brain perfusion, a graphical analysis[1,2] has been employed in radionuclide scintigraphy with technetium-99m hexamethylpropylene amine oxime (^{99m}Tc-HMPAO).[3–5] The method facilitated acquisition of a unidirectional influx constant (k_u) of the tracer from the blood to the brain without arterial blood sampling. In this study, we used the analysis in technetium-99m pertechnetate (^{99m}Tc) thyroid scintigraphy, and the new method for the quantitative assessment of the transfer process of ^{99m}Tc from the blood to thyroid tissue was evaluated.

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MATERIALS AND METHODS

Theory of the graphical analysis.

Gjedde and Patlak reported a theoretical model of blood-tissue tracer exchange as follows[1,2]:

In a unidirectional transfer process, tissue radioactivity, as a function of time [$B(t)$], is expressed

$$(1)\quad B(t) = k_u \int_0^t A(\tau)d\tau + V_n \times A(t)$$

Where $A(t)$ is the arterial activity as a function of measurement time (t), τ is time, k_u is the unidirectional influx rate, V_n is the initial nonspecific distribution volume of the tracer.

Dividing Eq. (1) by $A(t)$ yields

$$(2)\quad B(t)/A(t) = k_u \int_0^t A(\tau)d\tau/A(t) + V_n$$

The graphical approach by plotting $B(t)/A(t)$ versus $\int_0^t A(\tau)d\tau/A(t)$ gives an unidirectional influx rate of k_u as a slope of a straight line.

Patients

Thirty adult subjects were studied: 3 with Basedow's disease, 1 with functioning thyroid adenoma, 1 with Hashimoto's disease, and 25 in euthyroid state.

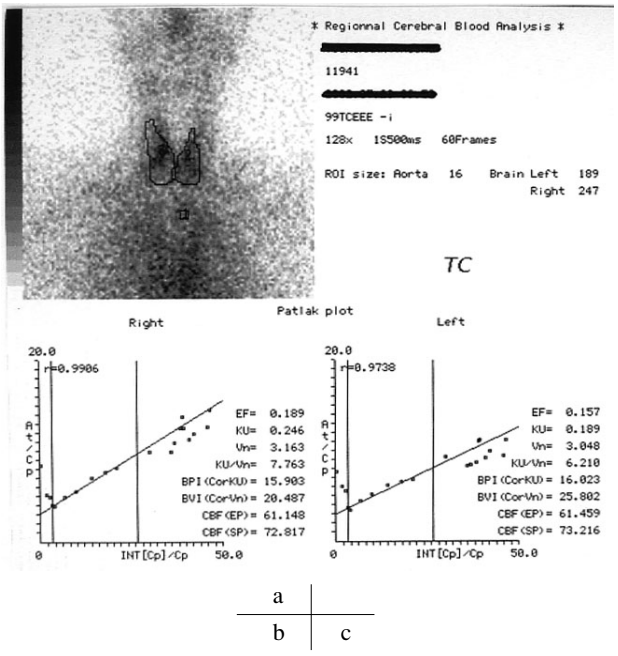

Fig. 1 The image of the data of a normal subject calculated by the software of Toshiba gamma camera system GCA7200. (a) ROIs were drawn over the aortic arch and the bilateral thyroid lobes on the ^{99m}Tc thyroid image at 30 minutes after the injection. (b) Data of $B(t)/A(t)$ versus $\int_0^t A(\tau)d\tau/A(t)$ of the right lobe were plotted on a graph. It gave a straight line within the first 30 seconds after the injection. The slope of the line (k_u) was 0.246 and TPI was 15.9. (c) Data of $B(t)/A(t)$ versus $\int_0^t A(\tau)d\tau/A(t)$ of the left lobe.

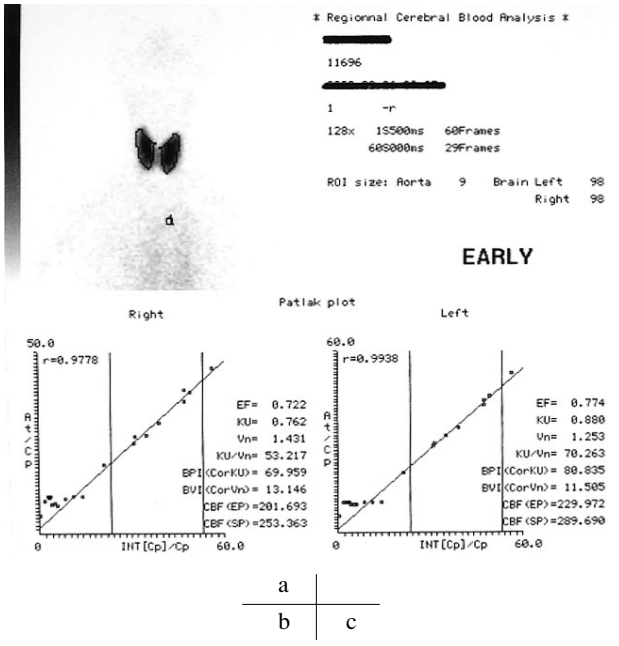

Fig. 2 The image of the data of a patient with Basedow's disease. (a) ROIs were drawn over the aortic arch and the bilateral thyroid lobes on the ^{99m}Tc thyroid image at 30 minutes after the injection. (b) Data of $B(t)/A(t)$ versus $\int_0^t A(\tau)d\tau/A(t)$ of the right lobe were plotted on a graph. The slope of the line (k_u) was 0.762 and TPI was 70.0. (c) Data of $B(t)/A(t)$ versus $\int_0^t A(\tau)d\tau/A(t)$ of the left lobe.

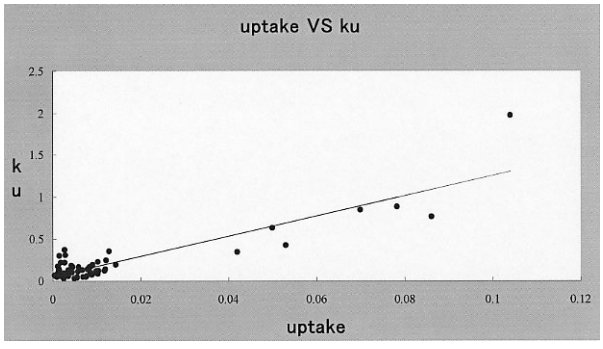

Fig. 3 Correlation between k_u and ^{99m}Tc uptake. K_u showed good correlation with ^{99m}Tc uptake ($Y = 12.0X + 0.052$, r = 0.892, $p < 0.001$).

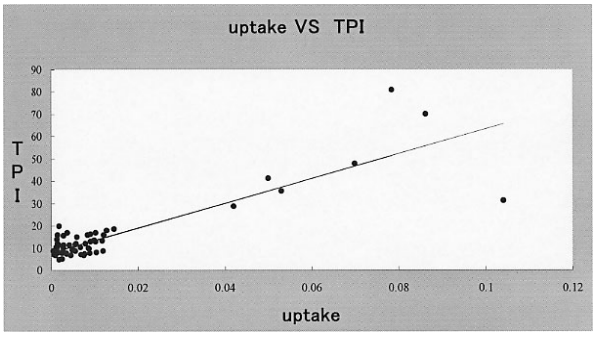

Fig. 4 Correlation between TPI and ^{99m}Tc uptake. TPI showed good correlation with ^{99m}Tc uptake ($Y = 555X + 7.90$, r = 0.864, $p < 0.001$).

Methods

Patients were positioned in the supine position, facing a rectangular large field gamma-camera (Toshiba GCA7200). The camera was set to monitor the passage of ^{99m}Tc through the heart to the thyroid. After the bolus injection of 111 MBq of ^{99m}Tc into the right brachial vein, the data were recorded on a 128 × 128 matrix as 60 frames of 1.5-second duration.

Regions of interest (ROIs) were placed over the aortic arch (ROI_{aorta}) and bilateral thyroid lobes ($ROI_{thyroid}$) (Fig. 1a). The activity of the aortic arch was monitored instead of the arterial activity as an input function of the graphical analysis. Time-activity curves for these ROIs were processed with a 5-point smoothing technique. The time delay of the thyroid activity curve to the aortic arch activity curve was corrected by matching the peak times of these curves. Data of $B(t)/A(t)$ versus $\int_0^t A(\tau)d\tau/A(t)$ were plotted on a graph (Fig. 1 (b, c)).

When the data gave a straight line, the slope (k_u) was measured. The value of k_u is changed by ROI size, and a

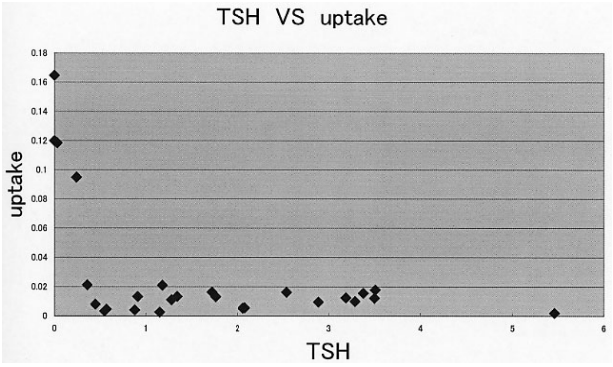

Fig. 5 The value of ^{99m}Tc uptake versus the value of serum TSH.

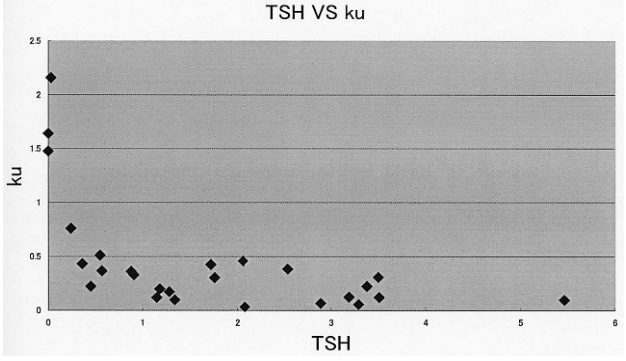

Fig. 6 The value of k_u versus the value of serum TSH.

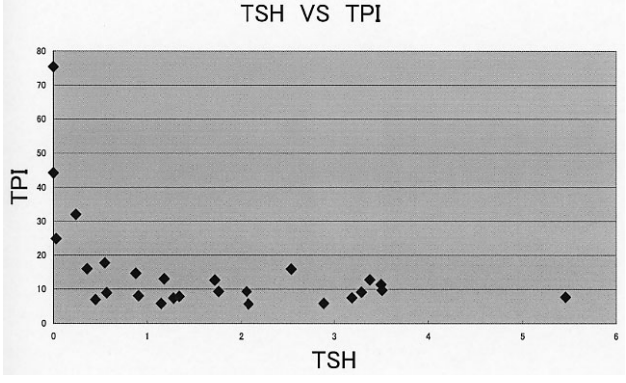

Fig. 7 The value of TPI versus the value of serum TSH.

new index was developed as follows:

Thyroid perfusion index (TPI)

$= 100 \times k_u \times 10 \times (\mathrm{ROI_{thyroid}}\ \mathrm{size})/(\mathrm{ROI_{aorta}}\ \mathrm{size})$.

This process made it possible to compare TPI among subjects in the standardization where the ratio of $\mathrm{ROI_{thyroid}}$ size to $\mathrm{ROI_{aorta}}$ size is set as 10. This series of data analysis to calculate k_u and TPI was performed using software for the measurement of regional cerebral blood flow equipped in Toshiba gamma camera system GCA7200.[3]

For the evaluation of these new indices of k_u and TPI, serum TSH concentration and ^{99m}Tc thyroid uptake were measured. The radioactivity of the syringe was counted before and after the injection. Thyroid image was acquired at 30 min after the injection. ROIs placed on bilateral thyroid lobes were drawn. ^{99m}Tc thyroid uptake was calculated as a rate of the injected activity, taking into account net injected counts, background correction and isotope decay correction.[6,7]

Statistics. Pearson's correlation and linear regression were calculated between k_u and ^{99m}Tc thyroid uptake. The analysis was also calculated between TPI and ^{99m}Tc thyroid uptake. An F test was used to determine whether the relationship between these parameters differed significantly from the line of identity.

RESULTS

A normal subject and a patient with Basedow's disease were shown in Figures 1 and 2. The figure was one of pictures obtained from a series of data analysis using the software. In the figures, ROIs drawn over the aortic arch and the bilateral thyroid lobes were shown. Data of $B(t)/A(t)$ versus $\int_0^t A(\tau)d\tau/A(t)$ of the lobe were plotted on the graphs and gave straight lines within the first 30 seconds after the injection of ^{99m}Tc.

In the other twenty-eight subjects, the graphical analysis also gave a straight line within the first 30 seconds after the injection of ^{99m}Tc.

The values of k_u and TPI of all thyroid lobes were 0.210 ± 0.301 (mean ± SD) and 15.2 ± 14.3 (mean ± SD). The values of k_u versus ^{99m}Tc uptake of all lobes were plotted (Fig. 3), and statistical analysis was performed. K_u showed good correlation with ^{99m}Tc uptake ($Y = 12.0X + 0.052$, $r = 0.892$, $p < 0.001$). TPI also showed good correlation with ^{99m}Tc uptake ($Y = 555X + 7.90$, $r = 0.864$, $p < 0.01$) (Fig. 4).

The values of ^{99m}Tc uptake, k_u and TPI versus the values of serum TSH of all subjects were plotted in Figures 5–7. The hyperthyroid patients with low values of TSH showed high values of ^{99m}Tc uptake, k_u and TPI.

DISCUSSION

The graphical analysis was developed to obtain unidirectional influx constant (k_u) of a tracer from blood to brain.[1,2,8] Matsuda developed the method using ^{99m}Tc-HMPAO for a quantitative evaluation of brain perfusion.[3–5] The graphical method has been also developed to renal study using ^{99m}Tc-DTPA[9] and ^{99m}Tc-MAG3[10,11] and hepatic study using ^{99m}Tc-DTPA-galactosyl-human serum albumin.[12,13]

In this study, we applied this method to thyroid study using ^{99m}Tc. The graphical analysis gave a straight line in all subjects, indicating that the unidirectional transfer uptake from blood to thyroid tissue was present in the linear phase and the influx constant (k_u) could be measured by this method. We proposed TPI as a new index corrected by the ROI size of thyroid and aorta.

The values of k_u and TPI were calculated by the software for the brain perfusion study using the graphical analysis, which was available in Toshiba gamma camera system GCA7200. It took only a few minutes per patient, and it did not require any special skill of computer analysis. The activity of aorta was taken as the arterial input function, and this method was not invasive.

^{99m}Tc thyroid uptake has been used as a measure of thyroid function.[7] K_u and TPI showed good correlation with ^{99m}Tc thyroid uptake. Patients with low values of serum TSH showed high values of ^{99m}Tc uptake, k_u and TPI. K_u and TPI are expected as new indices of thyroid function.

Information about thyroidal blood flow is useful for surgical operations which sometimes cause excessive bleeding. Especially in operations for Basedow's disease, thyroid bleeding may cause critical condition. Considering that k_u and TPI are determined at the timing of the first pass of ^{99m}Tc, the two indices may be helpful especially in the evaluation of thyroid perfusion.

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