Studies of the correlation between dual-source CT measured thyroid iodine concentrations, contents and thyroid function

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Abstract

Background The aim of this study is to investigate the correlation between dual-source CT measured iodine concentration, total iodine content and blood measured thyroid parameters.

Methods Dual-source CT was used to scan the neck of thyroid patients. The mean iodine concentration and thyroid tissue volume were measured to calculate the total iodine content of thyroid. Relevant test of triiodothyronine (FT3), total triiodothyronine (TT3), total thyroxine (TT4), free thyroxine (FT4), and thyroid hormone (TSH) were conducted. The correlation of thyroid mean iodine concentration and total iodine content with blood measured thyroid function was analyzed.

Result The total iodine content in thyroid was positively correlated with FT3, but negatively correlated with TSH. The mean iodine concentration of thyroid was positively correlated with both FT3 and TT3.

Conclusion The thyroid iodine content measured by dual-source CT can be used to determine the human iodine nutritional status and evaluate thyroid functions, which will provide help for the diagnosis and treatment of thyroid diseases.

Background

Iodine is one of the necessary trace elements for human, and it is also the raw material for the synthesis of thyroid hormones. Thyroid gland is the main storage organ of iodine in human body. Both iodine deficiency and iodine excess can cause changes to the morphology and function of thyroid [1.2]. Therefore, the measurement of thyroid iodine is not only helpful to determine human iodine nutritional status, but also has a certain value for the evaluation of thyroid function. Previous studies of measuring iodine concentration in phantom showed that dual-source CT was highly accurate in measuring iodine concentration [3.4]. Shao Weiguang[5] and others proved that gemstone energy spectrum CT imaging made measurement of iodine concentration more convenient, which can help to evaluate thyroid function. Some other studies also have confirmed that thyroid volume measured by CT was relatively accurate [6.7]. Therefore, the dual-source CT can be used to measure the total iodine content of thyroid, which is calculated by the mean iodine concentration multiply thyroid volume. Duong Duc Bin[8]et al. studied the relationship between dual-source CT measured thyroid iodine concentration and iodine uptake rate in patients with hyperthyroidism, and concluded that iodine uptake rate of 3 hours was negatively correlated with iodine concentration. At present, there is no studies about the relationship

between CT measured thyroid iodine concentration, total iodine content and blood measured thyroid function. In this paper, we will study the correlation between dual-source CT measured thyroid mean iodine concentration, volume and total iodine content with blood measured thyroid function, so as to provide a theoretical evidence for evaluating iodine nutritional status and thyroid function by dual-source CT in the future.

Methods

Subjects

Patients who were suspected of cervical spondylosis or cervical diseases in the radiology department of our hospital were selected for cervical CT scanning from August 2017 to March 2019. All patients were required to have no underlying diseases, normal thyroid function by serological examination, and no taken of thyroid preparations or iodine-containing drugs recently. Exclusion criteria: (1) uneven thyroid density, with low-density lesions and calcification; (2) a history of thyroid surgery or thyroid artifacts seriously affected by the surrounding; (3) abnormal thyroid function. A total of 31 patients, aged 22-79 years, with an average age of 54.61±15.13 years, were enrolled in the study, including 16 males and 15 females. All the selected cases were approved by the hospital ethics committee, and informed consent was signed by the patients before scanning.

Computed tomography scanning and post-processing

The CT scanning was performed using Siemens Definition Flash. Scanning is ranging from the skull base to the thoracic entrance. The patient is supine on the examination bed. He is instructed to raise his mandible as high as possible and droop his shoulders to avoid the influence of clavicle artifacts. Breath holding and no swallowing instructions are set to avoid breathing and swallowing artifacts. Scanning parameters: A tube voltage 100 kV, reference current 186 mAs; B tube voltage Sn140 kV, reference current 125 mAs, fusion coefficient 0.5, pitch 0.65, open CARE Dose 4D, reconstruction layer thickness 1.5 mm, interval 1.5 mm. The iodine map was obtained by choosing “CT Dual Engergy” mode using Syngo. Via workstation. The iodine concentration and CT value were measured for three times. The average

value of ROI was set to 20 mm^2. The left and right thyroid volumes including isthmus of thyroid are obtained through outlined layer by layer, with the VOI Freehand option using the CT Bone Reading program. The mean iodine concentration and volume of normal thyroid tissue were measured, and the total iodine content (total iodine content = thyroid mean iodine concentration × thyroid volume) was calculated.

Detection of thyroid function

Fasting venous blood samples were collected in the morning, and serum free triiodothyronine (FT3), total triiodothyronine (TT3), free thyroxine (FT4), total thyroxine (TT4) and thyroid hormone (TSH) were detected by chemiluminescence immunoassay and analyzed by gamma-ray radioimmunoassay. The instrument obtains the corresponding results.

Statistical Analysis

SPSS 20.0 software was used for statistical analysis. The correlation between mean iodine concentration, volume, total iodine content, age and thyroid function was analyzed by Spearman correlation analysis. Statistical significance was defined at $p < 0.05$.

Results

The measurement of thyroid CT value, mean iodine concentration (Figure 1a,b), thyroid volume (Figure 2a,b) and total iodine content

The CT value of 31 adult thyroid tissues was 89.37±16.14 Hu, the average iodine concentration was 1.28±0.48 mg/ml, the volume of thyroid was 13.5±4.28 ml, and the total iodine content of thyroid was 16.89±7.42 mg.

Detection of Thyroid Function Related Indicators (Table 1)

A total of 30 cases were detected for the five thyroid function index, including FT3, FT4, TSH, TT3 and TT4. In the other case, only three out five thyroid function index were collected, namely FT3, FT4 and TSH.

Correlation analysis of age, mean iodine concentration, volume and thyroid iodine content with thyroid function index (Table 2).

Correlation analysis of the results showed that age was negatively correlated with FT3, while CT value was positively correlated with FT3 (Figure 3a,b). Total iodine content of thyroid was positively correlated with FT3 (Figure3c), and negatively correlated with TSH (Figure3d). Thyroid iodine concentration was positively correlated with both FT3 and TT3 (Figure e,f).

Table 1 Descriptive analysis of thyroid function

	FT3 （pmol/L）	FT4 （pmol/L）	TSH（μIU/ml）	T3（μIU/ml）	T4（pmol/L）
minimum	3.00	6.89	0.30	0.62	69.92
maximum	5.78	13.42	8.56	1.92	127.01
average	4.7274	10.4023	2.7223	1.4477	101.5583
standard deviation	0.69500	1.59359	1.90769	0.30156	11.75984
reference Range	3.9-7.0	7.64-16.03	0.34-5.6	0.34-5.6	69.97-152.52
sample size	31	31	31	30	30

Table 2 Correlation analysis between iodine level and thyroid function index Spearman

		FT3	T3	FT4	T4	TSH	CT（
age	r Value	-0.393*	-0.114	-0.031	0.358	0.11	-0.354
	P Value	0.029	0.549	0.867	0.052	0.557	0.051
volume	R Value	0.213	-0.032	-0.023	0.098	-0.318	-0.081
	P Value	0.25	0.866	0.904	0.606	0.081	0.663
total iodine content	R Value	0.462**	0.281	0.117	0.161	-0.429*	0.466**
	P Value	0.009	0.132	0.532	0.395	0.016	0.008
erage iodine concentration	R Value	0.400*	0.397*	0.009	0.157	-0.161	0.669**
	P Value	0.026	0.03	0.961	0.406	0.386	0.000
CT value	R Value	0.408*	0.112	0.000	-0.051	-0.276	
	P Value	0.023	0.556	0.998	0.787	0.113	
Sample size	N	31	30	31	30	31	31

Figure1

Figure2

Figure 1,a,b Measurement of iodine concentration in left and right lobes of thyroid by iodine mapping.

Figure2 a, b .Measurement of the volume of left and right lobes of thyroid by depicting the area of interest.

Figure 3. a. Correlation between age and FT3.

1. CT value and FT3distribution.
2. Total iodine content and FT3 distribution.
3. Total iodine content and TSH distribution.
4. Iodine concentration and FT3 distribution.
5. Iodine concentration and TT3 distribution.

Discussion

Thyroid gland is the main organ of iodine intake in human body, and about 20% of the iodine in human body is stored in the thyroid gland. Previous studies have shown that urinary iodine measurement can reflect the amount of human iodine intake. The correlation between urinary iodine and thyroid function has also been reported. However, measurement of iodine in urinary has many influencing factors, and it is difficult to reflect the iodine nutritional status of body through this single test [9.10]. On the other side, studies on thyroid iodine by dual-energy CT and EDCT were only limited to the measurement of iodine concentration in the region of interest. So far, there is no simple, effective and non-invasive method to measure thyroid iodine content.

Dual-source CT has two independent X-ray generation and detector systems. Two sets of spherical tubes can scan simultaneously. According to the fact that the attenuation coefficients of the same substance under different energy X-rays are different, dual-source CT scanning technology can not only distinguish iodine from other substances easily, but also can quantitatively calculate iodine concentration in the region of interest with high accuracy. The mean iodine concentration and volume of thyroid gland can be measured by dual-source CT, and the total iodine content of thyroid (total iodine content = thyroid mean iodine concentration × thyroid volume) can be calculated. Thyroid iodine concentration and total iodine content are relatively stable. Dual-source CT scanning can measure thyroid iodine concentration and total iodine content accurately, which are highly in consistent with the actual thyroid iodine concentration. It can be theoretically used as a reasonable method for the analysis of iodine nutritional status of the body.

The mean iodine concentration in thyroid gland with normal thyroid function in the population was 1.28±0.48 mg/ml, which was similar to that of 1.49±0.41 mg/ml measured by gemstone energy spectrum CT imaging technology by Shao Weiguang [5] et al. In this study, we found no correlation between thyroid volume and thyroid function, which may because that thyroid volume can be affected by many factors, such as height, weight, etc.

[11.12]. Serum FT3 showed statistically significant (P0.05) decrease with age, and this is in consistent with the conclusion of the study of Harman SM [13], which reported that FT3 and T3 decreased with age. Our study also implied that aging itself and non-thyroid diseases could lead to the decrease of serum T3 concentration in the elderly and this decrease may be due to the reduction of peripheral transformation rate from T4 to T3. It is showed that the mean iodine concentration of thyroid was positively correlated with both FT3 and TT3 ($P < 0.05$), and the total iodine content was positively correlated with FT3 ($P < 0.01$). It indicated that the mean iodine concentration of thyroid could reflect the level of FT3 and TT3 in serum to some extent. This may be attributed to the reduction of thyroid iodine storage and iodine intake with aging. As iodine is the main raw material for synthesis of thyroid hormones, the reduction of stored iodine in thyroid decreased the ability of thyroid to synthesize and release FT3 and TT3. Total iodine content in thyroid was negatively correlated with TSH ($P < 0.05$), which may be related to the decrease of serum FT3 and TT3 and the increase of serum TSH reactivity.

In this study, we concluded that thyroid CT values are positively correlated with iodine concentration and total iodine content. In theory, iodine is the main determinant of thyroid CT value. Previous studies on iodine solution measurement have confirmed that there is a strong correlation between CT value and actual iodine concentration [14]. In this study, CT values were correlate with FT3 ($P < 0.05$), but not with TT3 and TSH. This may be explained by the fact that measurement of thyroid tissue by CT value can only partly reflect the iodine content of thyroid, and it may also be affected by the density of thyroid tissue. Studies have shown that different thyroid disease tissues have different CT values, and in most cases, the CT values of thyroid diseases tissues are lower than normal thyroid tissues [15, 16]. Therefore, compared with CT value, the measurement of iodine concentration and iodine content has more advantages in determining the pathological changes of thyroid tissue and iodine ion content in thyroid. Thyroid diseases will lead to the reduction of iodine concentration and total iodine content. However, the degree of reduction will vary among different types of thyroid diseases. On the other hand, iodine content measurement by dual-source CT can also be helpful for the evaluation of therapeutic effect of

hyperthyroidism patients. Therefore, studies of the correlation between iodine concentration and iodine content with thyroid function in thyroid disease patients can be added to the future study, to make up for the deficiency of clinical practicability of this study.

Limitations Of The Study

There were still some limitations of this study. Firstly, we only had 31 patients. The correlation study showed much variability in each comparison. Secondly, we only studied the normal thyroid gland, not including the dysfunctional thyroids. In the future, we will include the correlation study of thyroid iodine content in patients with hyperthyroidism or hypothyroidism, and the study of the changes of thyroid iodine content after the treatment, so as to obtain more valuable clinical results. As ionizing radiation is co-occurring in CT examination, we will try to reduce the radiation dose to protect the patients. With the updating in equipment and technology, we can foresee that patients can have more accurate measurements with lower radiation doses in the future.

Conclusions

The relationship between thyroid iodine content and mean iodine concentration in adults and thyroid function was studied by dual-source CT dual-energy scanning technology. And we further proved that dual-source CT can be used to assess thyroid function and iodine nutritional status of the body. The measurement of thyroid iodine content and mean iodine concentration by dual-source CT is simple, fast and effective, which will provide new methods and ideas for the future study of iodine-related thyroid diseases and clinical diagnosis and treatment of thyroid diseases.

Declarations

Abbreviations

CT: Computed tomography; DECT: Dual energy computed tomography;

FT3: Free triiodothyronine; FT4: Serum free thyroxine; HU: Hounsfield unit;

ROI: Region of interest; TSH: Thyroid stimulating hormone

Authors' contributions

ZTL and DMP conceived the study and participated in its design, data collection, statistical analysis and drafting of the manuscript. RH reviewed and edited the manuscript;all authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Ethics approval and consent to participate

This study was approved by the ethics committee of Jining No.1 People's Hospital and informed written consent had been obtained from all of the patients.

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Figures

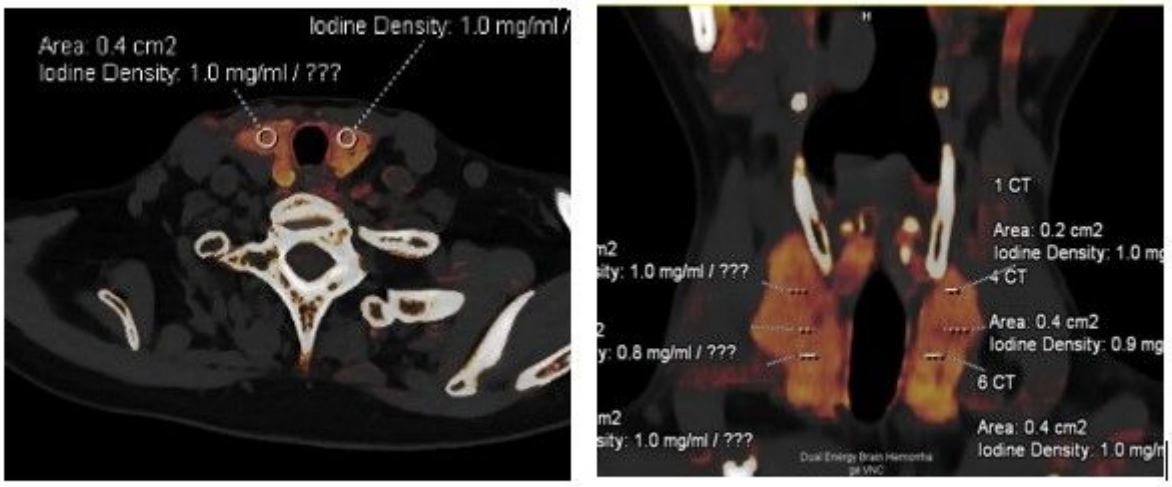

Figure1 a b

Figure 1

Measurement of iodine concentration in left and right lobes of thyroid by iodine mapping

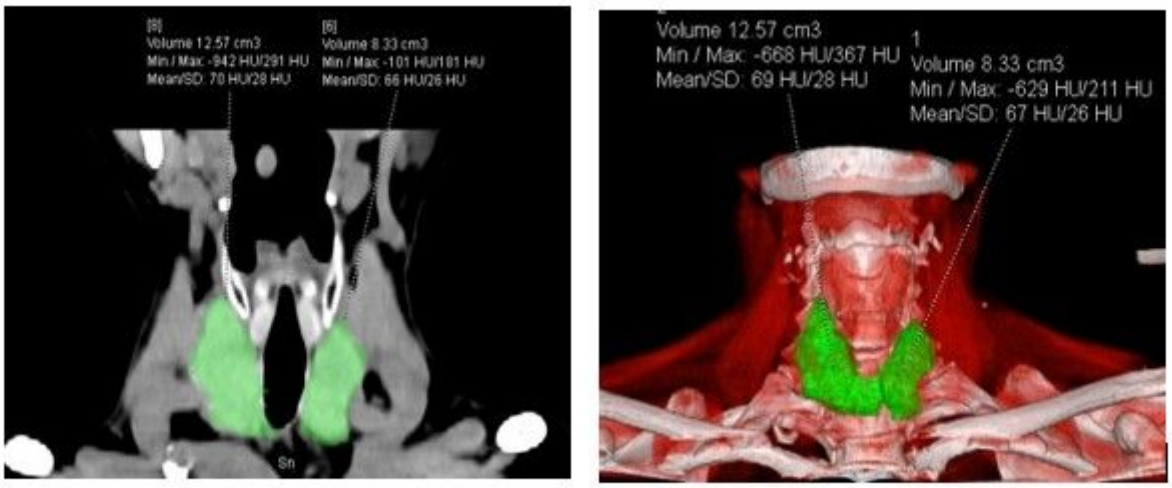

Figure2 a b

Figure 2

Measurement of the volume of left and right lobes of thyroid by depicting the area of interest.

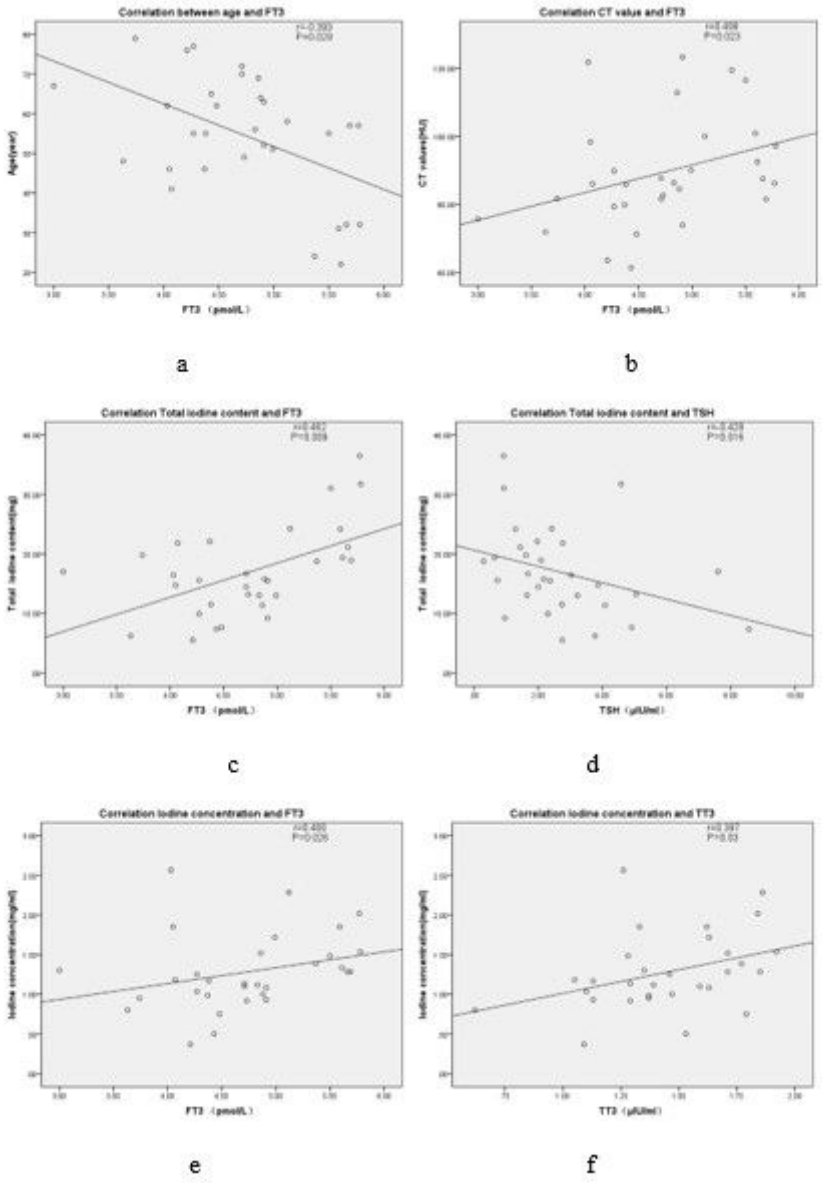

Figure 3

Correlation between age and FT3.b. CT value and FT3distribution.c. Total iodine content and FT3 distribution. d. Total iodine content and TSH distribution. e. Iodine concentration and FT3 distribution. f. Iodine concentration and TT3 distribution.