Iodine Quantification Using Dual-Energy Computed Tomography for Differentiating Thymic Tumors

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Purpose: The aim of the study was to explore the efficacy of iodine quantification with dual-energy computed tomography (DECT) in differentiating thymoma, thymic carcinoma, and thymic lymphoma.

Materials and Methods: Fifty-seven patients with pathologically confirmed low-risk thymoma (n = 16), high-risk thymoma (n = 15), thymic carcinoma (n = 14), and thymic lymphoma (n = 12) underwent chest contrast-enhanced DECT scan were enrolled in this study. Tumor DECT parameters including iodine-related Hounsfield unit (IHU), iodine concentration (IC), mixed HU (MHU), and iodine ratio in dual phase, slope of energy spectral HU curve (β), and virtual noncontrast (VNC) were compared for differences among 4 groups by one-way analysis of variance. Receiver operating characteristic curve was used to determine the efficacy for differentiating the low-risk thymoma from other thymic tumor by defined parameters.

Results: According to quantitative analysis, dual-phase IHU, IC, and MHU values in patients with low-risk thymoma were significantly increased compared with patients with high-risk thymoma, thymic carcinoma, and thymic lymphoma (P < 0.05/4). The venous phase IHU value yielded the highest performance with an area under the curve of 0.893, 75.0% sensitivity, and 89.7% specificity for differentiating the low-risk thymomas from high-risk thymomas or thymic carcinoma at the cutoff value of 34.3 HU. When differentiating low-risk thymomas from thymic lymphoma, the venous phase IC value obtained the highest diagnostic efficacy with the area under the curve of 0.969, and sensitivity, specificity, and cutoff value were 87.5%, 100.0%, and 1.25 mg/mL, respectively.

Conclusions: Iodine quantification with DECT may be useful for differentiating the low-risk thymomas from other thymic tumors.

Key Words: thymoma, thymic carcinoma, thymic lymphoma, thymic epithelial tumors, dual-energy computed tomography, iodine quantification

ORIGINAL ARTICLE

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M ediastinal masses include a spectrum of malignant tumors and benign lesions. Thymic neoplasms are the most common primary solid tumors of anterior mediastinum in adults, mainly including thymoma, thymic carcinoma, thymic lymphoma, and germ cell tumor.1 There are different optimal therapeutic strategies and prognosis for different thymic tumors.2 Low-risk (type A, AB, and B1) thymomas or early-stage (stages I and II) thymic epithelial tumors (TETs) are usually treated with surgery, and high-risk (type B2 and B3) thymomas or advanced stage (stages III and IV) TETs frequently require a multimodality approach, whereas lymphomas are managed with chemotherapy.3–5 Therefore, it has a clinical impact for physicians to accurately identify the tumor types before the treatment.

For the study of mediastinal tumors, computed tomography (CT) is generally the preferred imaging modality, presenting valuable diagnostic information in the detection, differentiation, staging, and prognosis evaluation of this lesions.6 Magnetic resonance imaging (MRI) is also effective because of its ability to provide excellent soft tissue detail.7 However, many thymic solid tumors cannot be accurately distinguished with the current information available from conventional CT and MRI.8,9 Dual-energy CT (DECT) is a relatively new technique offering specific tissue characterization through application of different x-ray spectra, which can be used to quantitatively measure iodine concentration (IC) reflecting the information about tumor contrast enhancement and angiogenesis.10–12 Compared with the conventional CT or perfusion CT, DECT could reduce the radiation dose and pseudoenhancement effects,13 which has been increasingly used for onologic imaging in recent few years.11,12,14–21 A previous CT research showed that the maximal contrast-enhanced range in type A and type AB thymomas were significantly higher than other TETs.22 Initial studies reported that DECT can be helpful in differentiating mediastinal tumors.11,20 In addition, there was a significant correlation between tumor angiogenesis and invasiveness in TETs.22 Therefore, we hypothesize that DECT parameters is useful in distinguishing the thymic tumors.

The purpose of our study was to explore the differential diagnostic value of iodine quantification with DECT in low-, high-risk thymoma, thymic carcinoma, and thymic lymphoma.

MATERIALS AND METHODS

Subjects

This retrospective study was approved by the local ethics committee, and informed written consent was waived. This study was conducted in accordance with the Declaration of Helsinki.

Between June 2016 and June 2017, 83 consecutive patients with suspected thymic tumors underwent thorax DECT examination. The inclusion criteria were as follows: (a) anterior mediastinal solid mass (excluding typical thyroid masses); (b) lesions larger than 1 cm in diameter based on the longest diameter; and (c) patient did not undergo biopsy or any treatment. Exclusion

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criteria were patients with thymic cyst (n = 6), thymic hyperplasia (n = 4), germ cell tumors (n = 3), and solitary fibrous tumor (n = 1) based on histopathology analysis, and 12 patients were excluded for no surgery. Finally, a total of 57 consecutive thymic tumor patients (30 men, 27 women; mean age = 48 years; age range = 11–76 years) were enrolled based on the inclusion and exclusion criteria (Table 1, Fig. 1).

**Computed Tomography Examination**

All thorax CT examinations were performed on a 128-row CT scanner (Somatom Definition Flash; Siemens Healthcare, Forchheim, Germany). Computed tomography images were acquired during a single breath-hold from the thoracic inlet to the costophrenic angle level in the craniocaudal direction. Contrast medium was administered by a dual-head pump injector (Stellant; Medtron, Saarbruecken, Germany). A volume of 60 to 100 mL (1.2 mL/kg of body weight) iodixanol injection 320 (HengRui, JiangSu, China) was injected in forearm vein at a flow rate of 3 mL/s using a 20-G needle, followed by a saline flush of 30 mL at the same rate. After intravenous injection of contrast medium, the arterial phase scan was triggered automatically 5 seconds after the attenuation in distal thoracic aorta increased to a default threshold (100 HU), and the venous phase scan was started with a 35-second delay after the end of the arterial phase scan. The scan parameters were as follows: 2 different tubes voltages (100 kV and Sn 140 kV, reference tube currents 160/68 mAs, respectively), slice thickness of 5.0 mm, collimation of 128 × 0.6 mm, tube rotation time of 0.28 seconds, and pitch of 0.55.

The spectral information from dual-energy data was used to generate iodine maps in axial 1.5-mm slices. These maps are comparable with color-coded CT images, but the displayed voxel values base exclusively on materials identified by the algorithm as contrast agent.

With a weighting factor of 0.6, the 2 data sets from the 2 x-ray tubes were fused to virtual images corresponding to a 120 kV scan (in the following, these images will be referred to as “conventional grey-scale CT”) and were reconstructed into axial 3-mm slices using a standard soft tissue reconstruction kernel (Q30f medium smooth). Virtual monochromatic 70-keV images, synthesized from dual-energy CT data, that are known to be similar to conventional 120-kV images.

**Table 1. Clinical and Demographic Characteristics of 57 Thymic Tumor Patients**

| Patients' Characteristics | Value |
|--------------------------|-------|
| Age, y                   | 47.7 ± 2.1 |
| Range                    | 11–76 |
| Sex, n (%)               |       |
| Male                     | 30 (52.6) |
| Female                   | 27 (47.4) |
| Major clinical symptoms, n (%) |     |
| Myasthenia gravis        | 6 (10.5) |
| Chest pain               | 11 (19.3) |
| Other                    | 27 (47.4) |
| No symptom               | 13 (22.8) |
| Method for obtaining pathologic results, n (%) |     |
| Surgery                  | 43 (75.4) |
| Thoracoscope             | 23 (40.4) |
| Thoracotomy              | 20 (35.1) |
| Percutaneous puncture     | 14 (24.6) |
| Histological type, n (%) |       |
| Thymoma                  | 31 (54.4) |
| A                        | 2 (3.5) |
| AB                       | 12 (21.1) |
| B1                       | 2 (3.5) |
| B2                       | 12 (21.1) |
| B3                       | 3 (5.3) |
| Thymic carcinoma         | 14 (24.6) |
| Squamous cell carcinoma  | 10 (17.5) |
| Neuroendocrine carcinomas| 4 (7.0) |
| Thymic lymphoma          | 12 (21.1) |
| T lymphoblastic lymphoma | 5 (8.8) |
| Diffuse large B-cell lymphoma | 3 (5.3) |
| Hodgkin lymphoma         | 3 (5.3) |
| MALT lymphoma            | 1 (1.8) |

MALT indicates mucosa-associated lymphoid tissue.

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**Image Analysis**

All data were transferred to a dedicated workstation (syngo. via, VB10B; Siemens Healthcare). The CT data was analyzed by 1 experienced radiologists (W.Q.Y., with 8 years of experience in chest CT imaging), who was aware that the patients had thymic tumors, but he was blinded to the pathological types of the tumors.

On conventional CT images, the tumor maximum and mean diameter, shape, boundary, necrotic or cystic changes, calcification, mediastinal lymphadenopathy, and presence of pericardial or pleural effusion were analyzed. The longest dimension (a) and the greatest perpendicular diameters (b) of the tumor were measured at the level where the tumor appeared largest on the horizontal-sectional image, and the other longest dimension (c) were obtained on sagittal or coronal slice. The mean diameter was calculated by (a + b + c)/3. The tumor shape was evaluated based on the ratio of the long-axis diameter to the short one. It was classified as round if the long-to-short-axis ratio was less than or equal to 1.5, oval if the ratio was greater than 1.5 but less than 2.0, or plaque if the ratio was greater than or equal to 2.0. Marginal characteristics were subclassified as smooth, lobulated, or irregular. Mediastinal lymphadenopathy was defined based on following criteria: short-axis diameter greater than 10 mm.

Dual-energy computed tomography data analysis was performed with commercial software (Syngo. via, dual-energy, liver virtual noncontrast, Siemens Healthcare). Reviewers selected the slice that showed the largest part of the tumor. Three-round ROIs were drawn manually using an electronic cursor, which were placed to include the solid tumor elements by defining ROI based on the Hounsfield unit (HU) on the virtual nonenhanced, arterial, and venous phase images, avoiding large vessels, calcification, obvious cystic, and necrotic areas. The mean ± SD ROI area was 94.2 ± 11.0 mm² (range = 60.0–110.0 mm²), respectively. The iodine maps and energy spectral curves were generated automatically (Figs. 1, 2, and the quantitative parameter: iodine-related HU (IHU), IC (milligram per milliliter), mixed HU (MHU), iodine ratio (IR, %), slope of energy spectral HU curve (λ) values both in artery and venous phase, and virtual noncontrast (VNC, HU) values were obtained.

The MHU was the CT attenuation value in postcontrast-enhanced HU, and the mean IHU was calculated as IHU = MHU – VNC. The mean IC (milligram per milliliter) of tumor was measured on the iodine images. The λ value was calculated as the CT attenuation difference at 2 energy levels (40 and 100 keV) divided by the energy difference (60 keV) from the spectral HU curve, according to the formula: $\lambda = \frac{|\text{CT}_{40\text{ keV}} - \text{CT}_{100\text{ keV}}|}{60}$.
Pathologic Diagnosis

The final diagnosis was determined by surgical specimen and confirmed with histopathological examination. Pathologic analysis was performed by a pathological expert. Tissue samples obtained from the specimens were routinely processed and stained for hematoxylin and eosin. Based on the criteria of the 2004 World Health Organization histological classification and Jeong simplification classification,23,24 thymic tumors were divided into the following 4 groups: low-risk thymoma (type A, AB, and B1), high-risk thymomas (type B2 and B3), thymic carcinoma, and thymic lymphoma.

Statistical Analysis

Numerical variables were denoted as mean and SD. The Kolmogorov-Smirnov test was used for assessing the normality of data distribution. Conventional CT features (including tumor shape, boundary, and presence of necrotic changes, calcification, lymphadenopathy, pericardiac, or pleural effusion) among low-, high-risk thymoma, thymic carcinoma, and thymic lymphoma groups were analyzed using the $\chi^2$ test. The tumor mean diameter, maximum diameter, and DECT parameters (IHU, IC, MHU, IR, and $\lambda$ values) were compared for differences among 4 groups.
based on one-way analysis of variance, and further post hoc multiple comparisons were performed with Bonferroni test (equal variances assumed) and Dunett T3 test (equal variances not assumed). Receiver operating characteristic (ROC) curve analyses were performed to determine optimum thresholds for differentiating the defined groups based on various parameters and to calculate sensitivity, specificity, and area under the curve (AUC) values. A $P$ value of less than 0.05 indicated a statistically significant difference. IBM SPSS 20.0 software (IBM Corp, Chicago, Ill) was used for statistical analysis.

RESULTS

The Clinical and Demographic Data

The patient demographic characteristics are shown in Table 1. The study group consisted of 30 males and 27 females with a mean ± SD age of 47.7 ± 2.1 years (range = 11–76 years). The major clinical presentations of the patients were myasthenia gravis (10.5%, 6/57 patients), chest pain (19.3%, 11/57), others (47.4%, 27/57), and the other 13 patients were without any discomfort (22.8%).

The pathologic classifications of the 57 thymic tumor patients demonstrated that 16 patients had low-risk thymomas (type A [n = 2], AB [n = 12], and B1 [n = 2]); 15 high-risk thymomas (type B2 [n = 12] and B3 [n = 3]); 14 thymic carcinomas (squamous cell carcinoma [n = 10] and neuroendocrine carcinomas [n = 4]); and 12 thymic lymphomas (T lymphoblastic lymphoma [n = 5], diffuse large B-cell lymphoma [n = 3], Hodgkin lymphoma [n = 3], and mucosa-associated lymphoid tissue lymphoma [n = 1]) (Table 1).

Comparison of Conventional CT Findings Among Low-, High-Risk Thymomas, Thymic Carcinomas, and Thymic Lymphomas

Comparisons of conventional CT features among 4 groups depending on World Health Organization pathological classifications of thymic tumor are shown in Table 2. Overall, tumor mean diameter, maximum diameter, boundary, necrotic or cystic changes, mediastinal lymphadenopathy, and presence of pericardial or pleural effusion differed among patients with 4 groups (all $P < 0.05$), whereas tumor shape and calcification did not differ depending on tumor pathological classifications (all $P > 0.05$).

Dual-Energy Computed Tomography Parameters Comparison Among Low-, High-Risk Thymomas, Thymic Carcinomas, and Thymic Lymphomas

Comparison of DECT parameters among patients with low-, high-risk thymoma, thymic carcinoma, and thymic lymphoma are shown in Table 3 and Figure 3. There were significant differences for artery-phase IHU (Fig. 3A), venous phase IHU (Fig. 3B), artery-phase IC (Fig. 3C), venous phase IC (Fig. 3D), $\lambda$ value,
dual-phase MHU, and IR among low-, high-risk thymoma, thymic carcinoma, and thymic lymphoma groups based on one-way analysis of variance (all \( P < 0.05 \)). In addition, pairwise comparison was performed, and the results revealed that the IHU, IC, and MHU values in both artery and venous phase were higher in low-risk thymoma group than in the high-risk thymoma, thymic carcinoma, and thymic lymphoma groups (IHU: 27.31, 15.15, 14.49, and 15.08 HU in artery phase, and 37.16, 22.15, 18.55, and 16.73 HU in venous phase; IC: 1.30, 0.67, 0.64, and 0.58 mg/mL in artery phase, and 1.75, 0.99, 0.82, and 0.70 mg/mL in venous phase; MHU: 64.06, 52.11, 51.35, and 48.18 HU in artery phase and 78.64, 61.39, 59.26, and 56.17 HU in venous phase, respectively, all \( P < 0.05/4 \).

In addition, venous phase IR value differed between low-risk thymoma and thymic carcinoma or thymic lymphoma groups \( (P < 0.05/4) \). However, the \( \lambda \) and artery-phase IR values did not differ significantly among groups.

### TABLE 2. Conventional CT Feature Comparisons Among Low-, High-Risk Thymoma, Thymic Carcinoma, and Thymic Lymphoma Patients

| Variable                        | LRT (n = 16) | HRT (n = 15) | TC (n = 14) | TL (n = 12) | \( P \)  |
|---------------------------------|-------------|-------------|-------------|-------------|--------|
| Mean diameter, cm              | 5.30 ± 3.30 | 4.63 ± 2.03 | 6.78 ± 3.53 | 7.97 ± 3.34 | 0.032* |
| Maximum diameter, cm           | 6.45 ± 4.15 | 5.71 ± 2.25 | 8.31 ± 4.42 | 10.11 ± 4.29 | 0.021* |
| Shape, n (%)                   |             |             |             |             | 0.344  |
| Round                           | 11 (68.8)   | 8 (53.3)    | 8 (57.1)    | 3 (25.0)    |        |
| Oval                            | 4 (25.0)    | 7 (46.7)    | 5 (35.7)    | 8 (66.7)    |        |
| Plaque                          | 1 (6.2)     | —           | 1 (7.2)     | 1 (8.3)     |        |
| Boundary, n (%)                |             |             |             |             | <0.001*|
| Smooth                          | 7 (43.8)    | 8 (53.3)    | 2 (14.3)    | 1 (8.3)     |        |
| Lobulated                      | 7 (43.8)    | 4 (26.7)    | 2 (14.3)    | 1 (8.3)     |        |
| Irregular                      | 2 (12.4)    | 3 (20.0)    | 10 (71.4)   | 10 (83.4)   |        |
| Necrotic or cystic changes, n (%)| 3 (18.8)   | 6 (40.0)    | 6 (42.9)    | 10 (83.3)   | 0.008* |
| Yes                             | 13 (81.2)   | 9 (60.0)    | 8 (57.1)    | 2 (16.7)    |        |
| No                              |             |             |             |             | 0.244  |
| Calcification, n (%)           |             |             |             |             | <0.001*|
| Yes                             | 3 (18.8)    | 4 (26.7)    | 4 (28.6)    | —           |        |
| No                              | 13 (81.2)   | 11 (73.3)   | 10 (71.4)   | 12 (100.0)  |        |
| Lymphadenopathy, n (%)         |             |             |             |             | <0.001*|
| Yes                             | 16 (100.0)  | 15 (100.0)  | 11 (78.6)   | 2 (16.7)    |        |
| No                              |             |             |             |             | <0.001*|
| Pericardial or pleural effusion, n (%)| 1 (6.3)  | —           | 9 (64.3)    | 9 (75)      |        |
| Yes                             | 15 (93.7)   | 15 (100.0)  | 5 (35.7)    | 3 (25)      |        |

*Significantly different among groups\( (P < 0.05) \).

### TABLE 3. The DECT Parameters Comparison Among Low-, High-Risk Thymoma, Thymic Carcinoma, and Thymic Lymphoma Groups

| Parameters               | LRT (n = 16)       | HRT (n = 15)       | TC (n = 14)        | TL (n = 12)        | \( P \)     |
|-------------------------|--------------------|--------------------|--------------------|--------------------|-------------|
| VNC, HU                 | 39.74 ± 7.89       | 38.27 ± 6.79       | 38.67 ± 7.56       | 34.97 ± 6.60       | 0.380       |
| IHU\(_a\), HU           | 27.31 ± 9.70*      | 15.15 ± 7.71*      | 14.49 ± 7.20*      | 15.08 ± 8.71*      | <0.001†     |
| IHU\(_v\), HU           | 37.16 ± 9.96*      | 22.15 ± 8.78*      | 18.55 ± 8.49*      | 16.73 ± 5.83*      | <0.001†     |
| IC\(_a\), mg/mL         | 1.30 ± 0.48*       | 0.67 ± 0.36*       | 0.64 ± 0.31*       | 0.58 ± 0.33*       | <0.001†     |
| IC\(_v\), mg/mL         | 1.75 ± 0.47*       | 0.99 ± 0.48*       | 0.82 ± 0.46*       | 0.70 ± 0.24*       | <0.001†     |
| MHU\(_a\), HU           | 64.06 ± 12.00*     | 52.11 ± 7.94*      | 51.35 ± 7.94*      | 48.18 ± 6.90*      | <0.001†     |
| MHU\(_v\), HU           | 78.64 ± 11.18*     | 61.39 ± 8.37*      | 59.26 ± 10.47*     | 56.17 ± 8.62*      | <0.001†     |
| IR\(_a\), %             | 12.51 ± 5.10       | 8.36 ± 4.59        | 7.97 ± 4.52        | 7.46 ± 3.94        | 0.015†      |
| IR\(_v\), %             | 43.44 ± 13.16*     | 31.91 ± 16.95      | 21.81 ± 9.11*      | 20.87 ± 7.62*      | <0.001†     |
| \( \lambda \)           | 0.16 ± 0.09        | 0.14 ± 0.09        | 0.12 ± 0.08        | 0.15 ± 0.06        | 0.725       |

The data are expressed as the mean ± SD.

*Represent a significant difference between the 2 groups based on post hoc tests \( (P < 0.05/4) \).

†Represent significant differences among 4 groups based on one-way analysis of variance \( (P < 0.05) \).

“\( a \)” denotes artery phase and “\( v \)” denotes venous phase.

HRT indicates high-risk thymoma; LRT, low-risk thymoma; TC, thymic carcinoma; TL, thymic lymphoma; \( \lambda \), slope of energy spectral HU curve.

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differ between low- and high-risk thymoma, thymic carcinoma, or thymic lymphoma groups \( (P > 0.05/4) \).

**Diagnostic Efficacy Analysis Results**

Because there were statistically significant differences between low- and high-risk thymoma or thymic carcinoma groups in terms of dual-phase IHU, IC, and MHU values, diagnostic efficacy was assessed by ROC curves. The efficacy of parameters in differentiating the low- from high-risk thymoma and thymic carcinoma in ROC analysis is showed in Table 4 and Figure 4A. The venous phase IHU value yielded the highest performance with an AUC of 0.893, 75.0% sensitivity, and 89.7% specificity for differentiating the low- from high-risk thymoma and thymic carcinoma at the cutoff value of 34.3 HU. When comparing with venous phase IHU value,

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### TABLE 4. Diagnostic Efficacy Comparisons of DECT Parameters in Differentiating the Defined Groups of Thymic Tumor

| Parameters | AUC | Sensitivity, % | Specificity, % | Cutoff value |
|------------|-----|----------------|----------------|--------------|
| LRT vs HRT + TC | | | | |
| IHU_a, HU | 0.846 | 75.0 | 82.8 | 20.65 |
| IHU_v, HU | 0.893 | 75.0 | 89.7 | 34.3 |
| IC_a, mg/mL | 0.866 | 68.8 | 86.2 | 1.05 |
| IC_v, mg/mL | 0.888 | 93.8 | 72.4 | 1.10 |
| MHU_a, HU | 0.804 | 56.3 | 100.0 | 64.9 |
| MHU_v, HU | 0.888 | 75.0 | 96.6 | 75.4 |
| LRT vs TL | | | | |
| IHU_a, HU | 0.836 | 93.8 | 66.7 | 14.15 |
| IHU_v, HU | 0.943 | 87.5 | 91.7 | 24.95 |
| IC_a, mg/mL | 0.904 | 87.5 | 75.0 | 0.65 |
| IC_v, mg/mL | 0.969 | 87.5 | 100.0 | 1.25 |
| MHU_a, HU | 0.862 | 68.8 | 100.0 | 59.15 |
| MHU_v, HU | 0.937 | 87.5 | 91.7 | 65.95 |

“a” denotes artery phase and “v” denotes venous phase.

HRT indicates high-risk thymoma; LRT, low-risk thymoma; TC, thymic carcinoma; TL, thymic lymphoma.
the other values also achieved the relatively high diagnostic efficacy, the AUC for artery-phase IHU, IC, MHU values, venous phase IC, and MHU value were 0.846, 0.866, 0.804, 0.888, and 0.888, respectively.

Similarly, in differentiating the low-risk thymoma from thymic lymphoma, the ROC analyses indicated that the venous phase IC value had the highest diagnostic efficacy with the AUC of 0.969, and sensitivity, specificity and the cutoff value were 87.5%, 100.0%, and 1.25 mg/mL, respectively. With regard to artery-phase IHU, IC, and MHU values as well as venous phase IHU and MHU values, the AUC were 0.836, 0.904, 0.862, 0.943, and 0.937, respectively, for differentiation of low-risk thymoma from thymic lymphoma (Table 4, Fig. 4B).

Discussion

It is clinically important to accurately differentiate the thymic tumors before treatment. In the current study, we evaluated the differential diagnostic value of DECT parameters in thymic tumors. The results revealed that DECT parameters (IC, IHU, and MHU) in both artery and venous phase in patients with low-risk thymoma were significantly increased compared with those in patients with high-risk thymoma, thymic carcinoma, or thymic lymphoma. In addition, we also determined the most appropriate cutoff values for each suggested parameter, which could potentially be used in clinical practice regarding the differential diagnosis of thymic tumor before treatment.

Conventional CT with multiplanar reconstruction provides better morphological information regarding tumor internal structure and local spread for preoperative assessment, which are helpful in differentiating different pathological classifications and clinical and local spread for preoperative assessment, which are helpful in better morphological information regarding tumor internal structure before treatment.

In this study, we also evaluated the diagnostic efficacy of DECT parameters in differentiating the various thymic tumors. The results showed that venous phase IHU value obtained the highest diagnostic efficacy with the AUC of 0.969, in differentiating low-risk thymomas from high-risk thymomas or thymic carcinomas.5,9,33 This interesting blood flow characteristic of TETs can be explained by a pathologic research, which demonstrated that the short-spindled variant (57% histologic patterns of thymoma type A and AB) was composed of oval to short spindle cells commonly arranged in a hemangiopericytic or microcystic pattern.34 Therefore, taken together, these results suggest that DECT parameters might be valuable for differentiating thymic tumors.

Our study had several limitations when interpreting the results. First, we drew the ROI manually, which might have introduced a sampling bias; the application of histogram analysis may improve diagnostic performance in future studies. Second, 14 patients did not undergo surgery because of the widespread invasion, and the final pathological results were proved by puncture biopsy, which may cause a study bias. Finally, because of the limited samples, we did not include the germ cell tumors, and further research is warranted to clarify this issue.

In summary, our study suggests that dual-phase DECT parameters including IC, IHU, and MHU in low-risk thymomas are significantly higher than in patients with high-risk thymoma, thymic carcinoma, and thymic lymphoma. Dual-energy computed differentiated the thymic tumors based on pathological classification. A, LRT vs HRT or TC by the IHU_a, IC_a, IHU_v, and IC_v values. B, LRT vs TL by the IHU_a, IC_a, IHU_v, and IC_v values. Note: “a” denotes artery phase and “v” denotes venous phase. HRT indicates high-risk thymoma; LRT, low-risk thymoma; TC, thymic carcinoma; TL, thymic lymphoma. Figure 4 can be viewed online in color at www.jcat.org.
tomography may be helpful in differential diagnosis of thymic tumors before subsequent treatment, with more quantitative information and higher efficacy compared with conventional CT examination.

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