The World Health Organization (WHO) histopathologic classification of thymic epithelial neoplasms has been considered to have prognostic value and can be directly correlated with clinical behavior. However, to the best of our knowledge, no studies have described the CT findings of thymic epithelial tumors by using the 2004 WHO classification.

To summarize the CT findings of different histological subtypes according to the 2004 WHO classification of thymic epithelial tumors.

Materials and Methods: We retrospectively reviewed all the histologically proven thymic epithelial tumors in our hospital from January 2003 to September 2007 according to the 2004 WHO classification. The initial chest CT scans and the image characteristics were reviewed. The CT findings for each histological subtype were also compared.

The CT images of 26 patients with thymic epithelial tumors were reviewed and there was some overlapping of CT findings among different histological subtypes. However, a high percentage of type A tumors were round shaped with smooth contours while more invasive thymomas and thymic carcinomas were more oval or plaque shaped with irregular contours. Type B3 thymic tumors and thymic carcinomas had a high percentage of tumor necrosis (75% and 78%, respectively) in comparison with type A and type AB tumors (25% and 25%, respectively). Calcifications were observed in type B group tumors without exception in our study. In addition, mediastinal involvement and metastasis were frequently seen in thymic carcinomas.

The CT features of different subtypes of thymomas tend to overlap. But irregular shape, presence of necrosis, mediastinal fat invasion, great vessel invasion, and metastasis are diagnostic features which suggest thymic carcinoma.

In 1999, the World Health Organization (WHO) proposed a classification of thymic epithelial tumors [1]. The classification was based on the histological morphology of the thymic epithelial cell and the relative amount of lymphocytic component. In 2004, an update of the WHO classification was published [2]. In the updated classification, the term “type C thymoma” was replaced by the term “thymic carcinoma”. In addition, thymic neuro-endocrine tumors were classified as thymic carcinomas [2, 3].

The WHO classification has been shown to be of prognostic significance in several studies [4-6]. Thymic carcinoma has the worst prognosis of all the histological subtypes. The 10-year disease-specific survival rate was about 29% for thymic carcinoma [6]. Thus, if we can predict the prognosis by using non-invasive procedures, more information can be provided before surgical management. Moreover, we can prevent tumor seeding resulting from unnecessary manipulation.

Chest CT is the most common tool to evaluate thymic epithelial tumors in current practice. In this article, we reviewed 26 cases of thymic epithelial tumors in a 1500-bed tertiary referral center, including image study and pathologic diagnosis. We tried to figure out the “malignant characteristics” in
CT images which might predict prognosis before surgical management.

MATERIALS AND METHODS

Patients
We retrospectively reviewed all the cases of thymic epithelial tumors treated from January 2003 to September 2007 in a 1500-bed tertiary referral medical center. The inclusion criteria for the study were: (1) the initial chest CT scan was performed in our hospital before operation, and (2) the diagnosis of thymic epithelial tumor was established by either surgical resection or biopsy.

Histopathologic evaluation
The histological samples of each patient were reviewed by an experienced pathologist based on the 2004 WHO classification. [2]. Thymomas have organotypic (thymus-like) features, including type A, AB, and B groups. Type A thymomas lack lymphoid component and consist of neoplastic, spindle-shaped epithelial cells. Thymomas with polygonal-shaped epithelial cells are type B thymomas, which are further classified into type B1, B2, and B3 according to the amount of lymphoid component. Type AB thymomas have both type A and type B components. Thymic carcinomas all contain non-organotypic malignant epithelial neoplasms other than germ cell tumors [2, 3, 7].

Chest CT protocol
The chest CT scans were performed in one of two spiral CT scanners (PQ2000 and PQ6000, Picker International Inc., Cleveland, OH, USA) with slice thickness and index of 8mm, rotation time of 1 s, tube voltage of 120kVp and tube current of 200mA. The scan range was from the thyroid cartilage to the base of both lungs. Intravenous contrast media injection was performed by manual hand push. All the scans were reviewed in three CT window width/level settings: mediastinal window (450 HU / 60 HU), lung window (1600 HU / -600 HU) and bone window (1250 HU / 450 HU). The characteristics of each tumor were listed, including tumor size, contour, and shape, presence of necrosis, calcification, and degree of enhancement, mediastinal involvement, and metastasis.

Image evaluation
The tumor size was measured in the greatest dimension of axial images. The contour of the tumor was divided into three categories: smooth, lobulated, and irregular (Fig. 1). Regarding the shape, we measured the long axis and short axis of the tumor at the axial image. If the ratio of the long axis and short axis was less than 1.5, the tumor was considered to be round shaped. If the ratio of the long axis and short axis was between 1.5 and 3, it was considered to be oval shaped. The remaining tumors, which had a ratio of long axis and short axis equal to or greater than 3, were considered to be plaque shaped (Fig. 2). For necrosis identification, an area of low attenuation, which was defined as less than 40 HU, was considered to be tumor necrosis (Fig. 3). For tumor enhancement, the degree of enhancement of the tumor was compared with that of the chest wall muscle after contrast enhancement. We classified the degree of enhancement into less than, equal to, and greater than the chest wall muscle. The great vessel involvement (Fig. 5), mediastinal fat invasion, and

Figure 1. Thymic tumor contours. a. Type A thymic tumor with smooth contour (arrow). b. Type AB thymic tumor with lobulated contour (arrow). c. Thymic carcinoma with irregular contour (arrow) and pleural metastasis (arrow-head).
pericardial effusion were considered as mediastinal involvement. In addition, we noted the presence of pleural effusion, pleural seeding, and lymph node metastasis.

Because of the retrospective nature and the focus of imaging findings, the study was conducted under a waiver of our hospital’s institutional review board. All information related to patient identification was deleted after the demographic data and images were obtained.

RESULTS

A total of 26 patients, including 12 females (46%) and 14 males (54%) were enrolled in our study after the initial CT scans and histology subtypes were reviewed. The average age was 53.7 ± 15.1 years (Table 1). According to the 2004 WHO classification [2-3], 9 of the patients had thymic carcinomas and 17 had thymomas.

The tumor sizes of each histological subtype are listed in Table 2, and the CT findings for each histological subtype are listed in Table 3.

There was some overlapping of CT find-
ings among the different histological subtypes. Nevertheless, some characteristics specific to invasive tumors and thymic carcinomas were found. For example, round shape was observed in all of the histological subtypes except for thymic carcinomas. In contrast, a high percentage of thymic carcinomas tended to have smooth contours (75% and 78%). One type B2 thymoma and one type B3 thymoma had irregular contours (7/9, 78%). On the other hand, although tumor necrosis was observed in all of the histological subtypes, type B3 thymomas and thymic carcinomas had a greater percentage of necrosis (75% and 78%, respectively).

Thymic carcinomas also showed a greater potential for adjacent structure invasion and distant metastasis such as mediastinal fat invasion, great vessel invasion (Fig. 5), and lymph node metastasis.

Considering tumor contour, type A tumors tended to have smooth contours (3/4, 75%) and thymic carcinomas had irregular contours (7/9, 78%). One type B2 thymoma and one type B3 thymoma had irregular contours. Therefore, irregular contours usually indicate high grade thymomas or thymic carcinomas.

Calcifications were unique to type B thymomas in our study (Fig. 4).

Table 3. CT findings of thymic epithelial tumors according to the 2004 WHO classification

<table>
<thead>
<tr>
<th>CT findings</th>
<th>WHO classification</th>
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<tbody>
<tr>
<td></td>
<td>Type A n=4</td>
</tr>
<tr>
<td>Contour</td>
<td></td>
</tr>
<tr>
<td>Smooth</td>
<td>3 (75)</td>
</tr>
<tr>
<td>Lobulated</td>
<td>1 (25)</td>
</tr>
<tr>
<td>Irregular</td>
<td>0</td>
</tr>
<tr>
<td>Shape</td>
<td></td>
</tr>
<tr>
<td>Round</td>
<td>4 (100)</td>
</tr>
<tr>
<td>Oval</td>
<td>0</td>
</tr>
<tr>
<td>Plaque</td>
<td>0</td>
</tr>
<tr>
<td>Presence of necrosis</td>
<td>1 (25)</td>
</tr>
<tr>
<td>Calcification</td>
<td>0</td>
</tr>
<tr>
<td>Degree of enhancement</td>
<td></td>
</tr>
<tr>
<td>Less than chest wall muscle</td>
<td>0</td>
</tr>
<tr>
<td>Equal to chest wall muscle</td>
<td>0</td>
</tr>
<tr>
<td>Greater than chest wall muscle</td>
<td>4 (100)</td>
</tr>
<tr>
<td>Pleural effusion</td>
<td>0</td>
</tr>
<tr>
<td>Pericardial effusion</td>
<td>0</td>
</tr>
<tr>
<td>Mediastinal fat invasion</td>
<td>0</td>
</tr>
<tr>
<td>Great vessel invasion</td>
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</tr>
<tr>
<td>Pleural seeding</td>
<td>0</td>
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<tr>
<td>Lymph node metastasis</td>
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</tbody>
</table>

* number in parentheses represents percentage
DISCUSSION

Thymic epithelial tumors are tumors which mostly arise from the anterior mediastinum with diverse pathologic findings. Using the 1999 WHO classification, many studies correlated the prognosis with different histological subtypes of thymic epithelial tumors [1]. Frank et al. reviewed and compared these studies and calculated the average of 10-year thymoma-specific survival for each histological subtype [6]. The 10-year thymoma-specific survival rates were reported to be 97% for type A, 95% for type AB, 92% for type B1, 81% for type B2, 62% for type B3, and 29% for type C thymoma (classified as thymic carcinoma in the 2004 WHO classification). Type C thymoma (thymic carcinoma in the 2004 WHO classification) had the worst prognosis among the 6 histological subtypes. As complete resection is an important post-operative prognosis factor and the tumor recurrence rate after complete resection was reported to be 0% for type A, 4.5% for type AB, 8.5% for type B1, 18.1% for type B2, and 28.6% for type B3. The WHO histological type might be a powerful tool for determining the treatment strategy, including extended thymectomy, induction therapy and adjuvant therapy. For type A or AB, extended thymectomy might not be required. But for type B thymomas, pre-operative induction chemotherapy, radiation therapy, and extended thymectomy should be considered, especially in cases with great vessel invasion. That was why we evaluated the different CT finding characteristics of each histological subtype in this study.

Tumor size

Considering tumor size, in our study, we measured the greatest dimension on the axial scan as in daily practice and found no significant difference between the histological subtypes. Some authors measured the short and long axis of the tumors for comparison. Tomiyama et al. found that type C tumors had greater short and long axis than type A and B2 tumors, but there was no significant difference between type C and type AB, B1, and B3.
tumors [8]. Jeong et al. found that thymic carcinomas were larger than low-risk (type A, AB, and B1) and high-risk thymomas (type B2 and B3). But statistical significance was only found between high-risk thymomas and thymic carcinomas [9].

**Tumor contour**
Smooth contours were seen in each histological subtype except for type B1 in our study. Of type A thymomas, smooth contour was found in 75%. Irregular contours were more frequently seen in thymic carcinomas (7 of 9 patients, 78%). As in the other studies, invasive tumors more often had irregular contours. The irregular contour was considered to be capsular invasion of thymic epithelial tumors [10, 11].

**Degree of enhancement**
Most of the tumors in our study had greater enhancement than the chest wall muscle. But since manual hand-push contrast enhancement was used, the timing of enhancement was variable in each patient. To improve this situation, a power injector can be used in further study to achieve more accurate control of the enhancement-timing.

**Calcifications**
Calcifications were only seen in the type B group tumors in our study, and most were present peripherally. Tomiyama et al. reported that calcifications were more often found in type B group tumors (44% of type B1, 61% of type B2, and 75% of type B3) than the other histological subtypes [8]. But in other studies, calcifications were found in both invasive thymomas and thymic carcinomas [12-13]. Moreover, calcifications are more frequently present in invasive thymomas than non-invasive thymomas. Calcifications within thymomas are commonly linear, thin, and peripheral and correspond to calcium deposition in the tumor capsule [10].

**Mediastinal involvement and metastasis**
Mediastinal involvement, including mediastinal fat invasion and great vessel invasion, was seen more frequently in type B2, B3 and thymic carcinomas in our study. This result was similar to that of the study by Jeong et al. [9]. In that study, the great vessel invasion observed in thymic carcinomas was considered to be a significant predictor of poor prognosis.

Some other features are often present in thymic carcinomas, including pleural effusion, pericardial effusion, pleural seeding, and lymph node metastasis. The potential for metastasis of thymic carcinoma should be considered. Thus, it is important to observe chest CT at different window levels to detect the possibility of metastasis.

**Limitations and conclusion**
There were some limitations of this study. The small patient number and small number of each subtype of tumor made it difficult to evaluate statistical significance. In addition, it would have been better to have a second radiologist in order to compare the results.

Because it was a retrospective study and total 10 patients (38%) in our study was lost in follow-up and we could not compare the outcome and survival rate of each histological subtype. Besides, 3 patients received biopsy only so it was impossible to obtain the complete margin from each tumor to evaluate the tumor invasiveness.

Moreover, the original chest CT protocol was single-slice CT with manual contrast media injection. Therefore, the difference between enhancement with and without contrast media could not be evaluated, and the enhancement time could not be controlled equally in each patient. The degree of tumor vascularity could not be evaluated from the chest CT scan during single phase images, either. It would be better to have dynamic chest CT scan by using injector to control the tumor enhancement time as well as tumor vascularity.

In conclusion, the CT findings for thymic epithelial tumors tended to overlap. However, we showed that the “malignant characteristics” of these tumors are irregular contours, area(s) of low attenuation, mediastinal involvement (mediastinal fat invasion and great vessel invasion) and metastasis.

**REFERENCES**


胸腺上皮瘤在電腦斷層上的表現：依據 2004 年 WHO 分類方法

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WHO 對於胸腺上皮瘤的分類方式有助於預後的評估，依據 2004 年新版的分類法，我們回顧在 2003 年一月到 2007 年九月間，26 個被診斷為胸腺上皮瘤的病人的病理組織分類以及在電腦斷層上的表現。

雖然在不同病理組織分類的胸腺上皮瘤的電腦斷層表現有彼此雷同的地方，但我們仍然觀察到 type A 的腫瘤表現出較多圓形且平滑的邊緣，而侵犯性較高的腫瘤以及胸腺癌則較多卵圓形、片狀型態並伴隨不規則的邊緣。此外，Type B3 和胸腺癌有較高比率的腫瘤壞死。而縱膈腔侵犯以及遠端轉移較常見於胸腺癌。在我們的研究裡，腫瘤的鈣化僅出現於 type B，並無例外。

總結來說，雖然不同病理型態的胸腺上皮瘤之影像表現有雷同的現象，但胸腺癌最常表現出不規則的邊緣、腫瘤壞死、縱膈腔侵犯、大血管侵犯以及遠端轉移。