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Research article

Useful computed tomography features for differentiating between focal atelectasis and pleural dissemination on preoperative evaluations of thymic epithelial tumors

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ABSTRACT

Purpose: Distinguishing between focal atelectasis (FA) and pleural dissemination (PD) is important for determining the optimal therapeutic strategy for thymic epithelial tumors (TET). This study aimed to identify useful computed tomography (CT) features for distinguishing between these two conditions.

Materials and methods: We retrospectively analyzed preoperative CT images of 27 TET, which included 40 PD and 40 FA lesions. Two radiologists independently interpreted the pleural lesions without knowing the final diagnosis. The CT images were evaluated to assess the lesion location, size, and shape, presence of a spinous shadow and ground glass opacities (GGO) near to the lesion, and the shortest distance from the lesion to the nearest peripheral pulmonary artery (PA).

Results: FA lesions tended to occur on the dorsal side (90%, $P = 0.024$); have shorter major and minor axes ($P < 0.001$), a triangular shape (43%, $P = 0.002$), a spinous shadow (45%, $P = 0.001$) and GGO (28%, $P = 0.006$); and be close to a peripheral PA ($P = 0.007$). Ninety percent of PD lesions were located in the left thorax, and all of them were ipsilateral to the tumor (both $P < 0.001$). The 9 examined factors exhibited sensitivity, specificity, positive predictive, and negative predictive values of 85%, 95%, 94%, and 86%, respectively, for diagnosing FA (when ≥3 factors were present), and 90%, 48%, 63%, and 83%, respectively, for diagnosing PD (when ≥4 factors were present).

Conclusion: The site, size, and shape of a lesion; the presence of a spinous shadow/GGO; and the distance to the nearest PA are useful for distinguishing between PD and FA.

1. Introduction

Thymic epithelial tumors (TET) include thymomas, thymic carcinoma, and thymic neuroendocrine tumors. Thymoma is the most common neoplasm of the anterior mediastinum and accounts for about one-fifth of mediastinal tumors [1,2]. The Masaoka classification is the most widely used system for staging thymomas, and it predicts patient prognosis well [3–5]. Previous studies have shown that complete resection is the most important prognostic factor for TET [3,4], and resection of the thymic tumor and the presence of disseminated nodules were found to be independent prognostic factors for disease-free survival in patients with resectable disseminated pleural or pericardial nodules in Masaoka stage IVa thymoma [6]. Hemithoracic irradiation is also used to treat pleural dissemination after surgery [7]. In a previous study, the 5-year survival rate of thymoma patients with disseminated nodules was 73.1% for patients who underwent resection and 0% for those that did not undergo resection [6]. In another study, the 5-year survival rate of stage III/IV thymoma was 93%, 64%, and 36% among the patients who underwent total resection, subtotal resection, and no operation, respectively [3]. Therefore, detecting pleural dissemination using computed tomography (CT) before surgery is important, as it helps surgeons to completely remove thymic lesions, including disseminated lesions (especially in the case of thymoma), and to improve treatment outcomes.

On the other hand, focal atelectasis, which can mimic pleural dissemination, is often seen on preoperative CT evaluations in TET patients, which makes it difficult to diagnose dissemination and determine its stage with accuracy. To the best of our knowledge, however, no previous studies have investigated ways of differentiating between focal atelectasis and pleural dissemination. So, the purpose of this study was to identify CT imaging features that are useful for distinguishing between focal atelectasis and pleural dissemination.

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Table 1
Patient and tumor characteristics.

Age	Median (range)	56 (24–78)
Gender	Male/female	15/12
Histology	Thymoma/thymic carcinoma	25/2
Masaoka stage	I/II/III/IVa/IVb	10/5/2/9/1
Location of primary tumor	Right/left	12/15

2. Materials and methods

2.1. Patients

We retrospectively investigated the cases of 45 TET patients who had undergone preoperative CT examinations at Nagoya City University Hospital between April 2007 and March 2014. Of these 45 patients, 18 with recurrent or no pleural lesions were excluded. The remaining 27 TET patients with focal atelectasis lesions (n = 40) or disseminated pleural nodules (n = 40) were included in this study. The characteristics of the patients and their tumors are shown in Table 1. In total, 93% of the patients had thymoma, and the Masaoka stage was classified as I in 37% of patients and IVa in 33% of patients. Three of the 12 right-sided TETs were at stage IV, while 7 of the 15 left-sided TETs were at stage IV. Three TETs had 2 disseminations, 2 TETs had 3 disseminations, and 1 each had 4, 5, 7, and 12 disseminations, respectively. Histological diagnoses were obtained based on examinations of surgical specimens or follow-up CT scans. Pleural nodules that had vanished by the time of the subsequent follow-up CT scan without treatment for TET being administered were diagnosed as focal atelectasis lesions. The study protocol was reviewed and approved by the institutional review board at Nagoya City University Hospital.

2.2. Image analysis

Two radiologists (with 16 and 13 years of experience, respectively) independently interpreted each pleural lesion in random order without knowledge of the final diagnosis. When the same patient had multiple lesions, we took great care to prevent multiple lesions from being seen during the image interpretation. CT images were obtained with a 3-mm slice thickness for the lung field (window width (WW), 1500; window level (WL), −550) and mediastinum (WW, 330; WL, 30) without contrast media and at 30 and 100 s after the administration of 100 mL of 300 mg I/mL contrast media (injected at a rate of 2 mL/s) (WW, 400; WL, 60). The CT scans were performed with a SOMATOM Definition (Siemens Medical Solutions, Forchheim, Germany) in 24 (89%) cases, and an Mx8000 IDT 16 (Philips Health, Cleveland, OH) in 3 (11%) cases. Prior to this study, various CT findings were evaluated by the authors, after excluding the two radiologists who were involved in the image interpretation. The following features were evaluated on the CT images: lesion location (right anterior, left anterior, right posterior, or left posterior), lesion size (major and minor axes), lesion shape (spindle-shaped, triangular, oval, or trapezoid) (Fig. 1), the presence or absence of a spinous shadow close to the pleural lesion (Fig. 2), the presence or absence of ground glass opacity (GGO) around the lesion (Fig. 2), and the shortest distance from the lesion to the nearest peripheral pulmonary artery (PA). Prior to the image interpretation, the laterality of the TET lesions was determined as right or left based on the position of the center of the tumor before treatment by the other radiologists, in order to judge whether the pleural dissemination/atelectasis lesions were ipsilateral or contralateral to the primary lesion. The location of each pleural lesion or atelectasis was classified into either anterior (ventral) or posterior (dorsal) based on the major axis of the thoracic cavity. The perpendicular distance from the end of the nearest PA to the lesion on the slice showing the lesion was defined as the shortest distance from the PA to the lesion. When the PA and the lesion were in contact, the distance was defined as 0 mm. The final interpretation was made by consensus. From these analyses, atelectasis factors (A-factors) and dissemination factors (D-factors), which were considered to be suggestive of atelectasis and dissemination, respectively, were identified, and the diagnostic accuracy of these two types of factors was evaluated.

2.3. Statistical analyses

The logistic regression analysis of imaging features was carried out using the software StatView for Windows version 5.0 (SAS Institute Inc., Cary, NC, USA). Other statistical analyses were performed using the software SPSS Statistics ver. 21 (IBM SPSS Statistics, IBM, Armonk, NY, USA). Differences in the distributions of the lesions among the 4 compartments and the shapes of the lesions were examined using the chi-square test. Differences regarding the ventrodorsal location, laterality, or ipsilaterality of the lesions and the frequencies of the spine and GGO were examined using Fisher's exact test. The major and minor axis lengths and the shortest distance from the lesion to the nearest peripheral PA were compared using the Mann-Whitney U test. Interobserver agreement between the two blinded readers during the subjective evaluations was assessed using the Cohen κ test as follows: slight, 0.0–0.20; fair, 0.21–0.40; moderate, 0.41–0.60; substantial, 0.61–0.80; and almost perfect, 0.81–1.00. P-values of < 0.05 were considered to indicate significant differences.

3. Results

The mean (± standard deviation) lengths of the major and minor axes of the focal atelectasis lesions were 5.0 ± 1.6 and 3.1 ± 0.9 mm, respectively, while those of the pleural dissemination lesions were 17 ± 12 and 8.4 ± 6.8 mm, respectively. The lengths of the major and minor axes of the focal atelectasis lesions differed significantly from those of the pleural dissemination lesions (both $P < 0.001$). There were striking differences in the most common sites of each type of lesion. Focal atelectasis was more frequently observed on the dorsal side ($P = 0.024$) (90% of atelectasis lesions were located on the dorsal side), whereas 70% of the disseminated lesions were found on the dorsal side. In addition, 90% of the pleural disseminations were located on the left side in this study ($P < 0.001$), and all of the disseminated nodules were found on the same side as the primary tumor, whereas atelectasis was seen on both the ipsilateral and contralateral sides ($P < 0.001$). Significant differences were also noted in lesion shape ($P = 0.002$), the frequency of the spinous shadow ($P = 0.001$), the frequency of GGO ($P = 0.006$), and the shortest distance from the lesion to the nearest peripheral PA ($P = 0.007$) (Table 2).

Since the longest major axis of focal atelectasis was 10 mm and the median size of dissemination was 12 mm, differentiation between atelectasis and small dissemination is considered important. So, we conducted a similar analysis for small lesions with a major axis ≤10 mm (Table 3). Probably due to the decrease in the number of disseminated lesions analyzed, the ventrodorsal location and the presence of GGO did not reach statistically significant levels, but otherwise, similar trends were observed as compared with Table 2.

Results of the logistic regression analysis are shown in Table 4. Imaging features that were closely related to other features could not be included in the analysis. The odds ratio for the ventrodorsal location indicates that when the lesion is located in the anterior part, the probability of dissemination would be 3.1 times higher than that of atelectasis. From the odds ratios, absence of GGO was the most important imaging feature to predict dissemination, and the minor axis < 4 mm (median for all lesions) was the most significant to predict atelectasis.

Overall almost perfect interobserver agreement (κ = 0.962) was seen between the two blinded readers (including with regard to diagnosis). The kappa statistics for the shape, spinous shadow, and GGO