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# The relation between CT findings and sputum microbiology studies in active pulmonary tuberculosis

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ABSTRACT

*Purpose:* To evaluate whether CT findings suggesting active pulmonary tuberculosis correlate with sputum microbiological studies, and to determine whether CT could predict infectivity.
*Materials and methods:* Total 108 patients with active pulmonary tuberculosis were enrolled. We reviewed CT findings and sputum microbiological studies. Then, we analyzed the statistical difference in CT findings between the positive and negative groups of each sputum microbiological study (AFB smear, PCR, and culture). Also, we divided the patients into five groups according to sputum AFB smear grade and analyzed linear trends of CT findings between the five groups.
*Results:* Both frequencies and extents of centrilobular micronodules (63% vs 38%, $p = 0.011$ for frequency; $1.6 \pm 1.6$ vs $0.6 \pm 1.1$, $p = 0.001$ for extent), tree-in-bud opacities (63% vs 33%, $p = 0.002$; $1.6 \pm 1.6$ vs $0.5 \pm 0.9$, $p < 0.001$, respectively), consolidation (98% vs 81%, $p = 0.003$; $2.7 \pm 1.5$ vs $1.3 \pm 1.1$, $p < 0.001$, respectively), and cavitation (86% vs 33%, $p < 0.001$; $1.5 \pm 1.2$ vs $0.4 \pm 0.7$, $p < 0.001$, respectively), were significantly increased in the sputum AFB-positive group than in the negative group. These four CT findings were increase in frequency and extent in the sputum PCR-positive group with or without statistical significance. They did not show significant differences between the sputum culture-positive and negative groups. As the AFB smear grade increased, frequencies and extents of centrilobular micronodules, tree-in-bud, consolidation, and cavitation also increased.
*Conclusion:* CT features representing active tuberculosis—centrilobular nodules, tree-in-bud, consolidation, and, cavitation—strongly correlate with the positivity and grading of AFB smear.


## 1. Introduction

In pulmonary tuberculosis (TB), CT provides valuable information for the diagnosis and management of the disease. Furthermore, CT can help distinguish active forms of the disease from its inactive forms [1,2]. The most common CT findings of active pulmonary TB are centrilobular micronodules, tree-in-bud opacities, consolidation, and cavitation [2]. Especially, centrilobular micronodules, tree-in-bud opacities, and cavitation are considered active disease processes [2–4]. Patients with sputum smear-positive TB are the most potent sources of infection. Moreover, the bacterial count from the smear correlates with the degree of infectiousness of the patient as well as the severity of the disease [1]. There have been a few studies about the relationship between CT findings and the positivity/grading of sputum smears [1,5]. In these studies, the presence of cavitation and consolidation correlated with the results of sputum studies. However, the presence of micronodules did not. This is unexpected because all micronodules (but not miliary) in active TB have been considered to have centrilobular distribution representing bronchogenic spread [2,6].

Recently, we reported that micronodules with perilymphatic distribution are common in pulmonary TB which may represent lymphatic spread of TB [7]. We thought that all of the micronodules visible on CTs in pulmonary TB may not be centrilobular distribution reflecting bronchogenic spread, and that the presence of micronodules by exception for ones showing perilymphatic and miliary distribution may correlate with results of sputum studies. Accordingly, our study aimed to evaluate whether CT findings of active TB, including the presence of centrilobular micronodules, correlate with sputum microbiological results

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and to determine whether CTs can predict the infectivity of pulmonary TB.

## 2. Materials and methods

This study was approved by The Catholic university of Korea St. Vincent's Hospital Institutional Review Board (VC14RISI0100), which waived informed consent. We selected 194 consecutive patients with active pulmonary TB, who obtained CT scans at the time of diagnosis from January 2010 to February 2013. We analyzed the patients' medical charts, microbiology studies' results, and pulmonary parenchymal changes on the CT scans.

Conventional CT with or without an intravenous administration of contrast medium (100 mL at 2–2.5 mL/s) and high resolution CT (HRCT) were obtained with two MDCT scanners. The decision to perform contrast enhancement was made by the attending clinicians based on their suspicion for malignancy or TB lymphadenitis from chest radiographs of the patients. Parameters for a LightSpeed VCT (General Electric Medical Systems, Milwaukee, WI, USA) were as follows: detector collimation, 64 × 0.625 mm; rotation time, 500 ms; pitch 1.375; 120 kV tube voltage; automatic tube current modulation. Parameters for a SOMATOM Definition Flash (Siemens Healthcare, Forchheim, Germany) were as follows: detector collimation, 128 × 0.6 mm; rotation time, 280 ms; pitch 1.5; 100 or 120 kV tube voltage; automatic tube current modulation. In the conventional CT, all images were reconstructed into axial images with 5-mm slice thickness at 5-mm intervals, coronal images with 3-mm slice thickness and high-spatial-frequency algorithm. For HRCT, axial and coronal images with 1-mm slice thickness at 5-mm intervals and high-spatial-frequency algorithm were obtained.

CT scans obtained before the administration of anti-tuberculous medication were analyzed for the presence and distribution of micronodules. The micronodules were defined as small rounded opacities with a diameter less than 7 mm and were classified by their distribution as either centrilobular, perilymphatic, or random [8]. We also noted the presence or absence of consolidation, cavitation, tree-in-bud, interlobular septal thickening, and bronchovascular bundle thickening which are well-known, common CT features of active TB [4,9,10]. The extent of each CT finding was recorded as the number of involved lobes (the lingula was considered as a separate lobe).

All CT scans and medical records were retrospectively reviewed by two chest radiologists with 4 and 11 years of experience. The two radiologists independently and blindly analyzed the CT scans for the presence or absence and extent of TB features. The interpretation of differences in the observed findings was based on a consensus between the two radiologists. We divided the patients into two groups according to the positivity of each sputum studies (AFB smear, PCR assay, and culture) and compared the CT findings using the Pearson chi-square test or Fisher's exact test for frequency and Mann–Whitney *U* test for extent. Also, we assigned the patients to five groups as per grading of the sputum AFB smear (0, no AFB seen; 1+, 1–9 AFB/100 fields; 2+, 1–9 AFB/10 fields; 3+, 1–9 AFB/field; 4+, >9 AFB/field) according to the number of visible AFB on slide. Then, we compared CT findings using the chi-square test for trend for frequency and Spearman's rank correlation for extent. *P* values less than 0.05 were considered statistically significant.

## 3. Results

Among 194 patients, 29 were excluded from this analysis due to a co-existing pulmonary disease (pneumonia, $n = 19$; pulmonary edema, $n = 4$; pulmonary hemorrhage, $n = 3$; severe emphysema, $n = 1$; diffuse interstitial pneumonitis, $n = 1$; and lung collapse due to extensive pleural TB, $n = 1$). We also excluded 37 patients who did not undergo sputum studies and 20 patients had clinical and radiological findings suggestive of a diagnosis of pulmonary TB and showed a successful response to anti-tuberculous drugs. Therefore, we ultimately evaluated CT findings (conventional CT, $n = 98$; HRCT, $n = 10$) from 108 patients with pulmonary TB (74 men and 34 women; mean age, 41 years; age range, 16–86 years). Twenty-one patients had a chronic illness, including diabetes ($n = 9$), chronic obstructive lung disease ($n = 9$), malignancy ($n = 3$), renal failure ($n = 1$), and collagen vascular disease ($n = 1$). Diagnoses of active pulmonary TB were confirmed by positive sputum microbiology results (acid-fast bacilli (AFB), $n = 63$; polymerase chain reaction (PCR), $n = 60$; culture, $n = 74$) in 96 patients. Twelve patients were diagnosed by positive microbiology results from bronchial lavage (AFB, $n = 4$; PCR, $n = 10$; culture, $n = 9$). The clinical characteristics and frequencies of various CT findings in patients are summarized in Table 1. The overall frequencies of micronodules, consolidation, cavitation, and tree-in-bud opacities which are well-known radiologic feature of active pulmonary TB were 94%, 92%, 66%, and 52%, respectively. Bronchovascular bundle thickening and interlobular septal thickening were also commonly seen (93% and 68%, respectively). For the distribution of micronodules, perilymphatic distributing micronodules (85%) were most common followed by centrilobular micronodules (54%). Only two patients had randomly distributing micronodules (Figs. 1, 2, and 3).

**Table 1**
The clinical characteristics and prevalence of CT findings in patients.

| Patients' characteristics | |
|---|---|
| Number of patients | 108 |
| Age | 41 ± 17 (16–86) |
| Sex (M:F) | 74:34 |
| Grade of sputum AFB smear | 1.3 ± 1.4 |
| AFB smear -positive sputum | 63/105 (60%) |
| PCR-positive sputum | 60/81 (74%) |
| Culture-positive sputum | 74/89 (83%) |
| CT findings | |
| Micronodules | 102 (94%) |
| Centrilobular | 58 (54%) |
| Perilymphatic | 92 (85%) |
| *Peribronchovascular* | 89 (82%) |
| *Septal* | 66 (61%) |
| *Subpleural* | 54 (50%) |
| Random | 2 (2%) |
| Tree-in-bud | 56 (52%) |
| Consolidation | 99 (92%) |
| Cavitation | 71 (66%) |
| Bronchovascular bundle thickening | 100 (93%) |
| Septal thickening | 73 (68%) |

Both frequencies and extents of centrilobular micronodules (63% vs 38%, $p = 0.011$ for frequency; 1.6 ± 1.6 vs 0.6 ± 1.1, $p = 0.001$ for extent), tree-in-bud opacities (63% vs 33%, $p = 0.002$; 1.6 ± 1.6 vs 0.5 ± 0.9, $p < 0.001$, respectively), consolidation (98% vs 81%, $p = 0.003$; 2.7 ± 1.5 vs 1.3 ± 1.1, $p < 0.001$, respectively), and cavitation (86% vs 33%, $p < 0.001$; 1.5 ± 1.2 vs 0.4 ± 0.7, $p < 0.001$, respectively), were significantly increased in the sputum AFB-positive group than in the negative group (Tables 2 and 3).

Regarding PCR, consolidation (98% vs 71%, $p = 0.001$; 2.6 ± 1.6 vs 1.1 ± 1.0, $p < 0.001$, respectively), and cavitation (78% vs 33%, $p < 0.001$; 1.4 ± 1.3 vs 0.4 ± 0.7, $p < 0.001$, respectively), were more frequent and increased extent in the sputum PCR-positive group. Extents of centrilobular micronodules were significantly increased in sputum PCR-positive group (1.5 ± 1.6 vs 0.8 ± 1.2, $p = 0.038$). However, frequencies of centrilobular micronodules (63% vs 38%, p = 0.072) and frequencies and extents of tree-in-bud opacities (60% vs 38%, $p = 0.083$; 1.5 ± 1.6 vs 0.8 ± 1.2, $p = 0.065$, respectively) were insignificantly greater in the sputum PCR-positive group. Frequencies and extents of centrilobular micronodules, tree-in-bud