Chest Tuberculosis: Radiological Classification According to Current Concepts

Sun Young Jeong, Jeong Jae Kim, Gukmyung Choi, Seung Hyung Kim, and Im Kyung Hwang

Department of Radiology, Jeju National University School of Medicine, Jeju, Korea

(Received November 29, 2013; Revised December 6, 2013; Accepted December 13, 2013)

Abstract

Tuberculosis(TB) is one of the most important infectious diseases, causing high mortality and morbidity worldwide. The traditional imaging concept of primary and reactivation TB recently has been challenged on the basis of DNA finger printing; the radiological findings are closely related with the patient's immune status rather than the elapsed time after the infection. In this regard, we need to use new radiological classification instead of using the inappropriate previous terminologies (primary and reactivation TB). In this paper, we will classify the imaging findings of chest TB as follows; parenchymal TB (air-space consolidation, focal nodular lesion and linear density, cavity, tuberculoma, fibrosis-scar-destruction), tracheobronchial TB, miliary TB, lymph node TB, pleural TB, and pericardial TB. (J Med Life Sci 2013;10(2):163-174)

Key Words : chest tuberculosis, current concepts, radiological classification

Introduction

Tuberculosis (TB) is an airborne infectious disease caused by *Mycobacterium tuberculosis* and is a major cause of morbidity and mortality worldwide[1-3]. In 2012, an estimated 8.6 million people developed TB and 1.3 million died from the disease[4]. Most cases occur in Southeast Asia and Africa.

Patients with active pulmonary TB may be asymptomatic, have mild or progressive dry cough, or present with multiple symptoms including fever, fatigue, weight loss, night sweats, and a cough that produces bloody sputum[5].

If TB is detected early and fully treated, people with the disease quickly become noninfectious and eventually cured. The prompt diagnosis of TB is essential for community public health infection control. Unfortunately, acid-fast bacilli are found in the sputum in a limited number of patients with active pulmonary TB. Therefore, the imaging diagnosis would provide an appropriate therapy for infected patients before the definitive diagnosis by the bacteriology[3,6].

New Concept of Radiologic Manifestation of Tuberculosis

Patients who develop disease after initial exposure are considered to have primary TB, and others who develop disease as a result of reactivation of a previous focus of TB or due to reinfection are considered to have postprimary TB.

Traditionally, it was believed that the clinical, pathologic, and radiologic manifestations of postprimary TB infection were quite distinct from those of primary TB infection[3,7]. Focal or patchy heterogeneous consolidation or reticulonodular opacities in the upper lobes and cavitation were considered as the manifestation of postprimary TB, whereas hilar or mediastinal lymph nodes enlargement and homogeneous airspace consolidation were considered as the manifestation of primary TB[8].

However, this concept has been recently challenged on the basis of DNA fingerprinting. DNA fingerprint pattern with restriction fragment length polymorphism(RFLP) analysis of *M. tuberculosis* isolates can give clinicians an insight into the transmission of TB. Isolates from patients infected with epidemiologically unrelated strains of TB have different RFLP patterns, whereas those from patients with epidemiologically linked strains generally have identical RFLP patterns. Therefore, clustered cases of TB, defined as those in which the isolates have identical or closely related genotypes, have usually been transmitted recently. In contrast, cases in which the isolates have distinctive genotypes generally are a reactivation of infection[3,9-11].

Recent studies based on DNA fingerprinting showed that the radiographic features are often similar in patients who have a primary disease and those who have postprimary TB[12,13]. Therefore, time from acquisition of infection to the development of clinical disease does not reliably predict the radiographic appearance of TB. The only independent predictor

Correspondence to : Sun Young Jeong, MD
Department of Radiology, Jeju National University School of Medicine, 102 Jejudaehakno, 690-756, Jeju, Korea
E-mail: sy7728.jeong@gmail.com

"This research was supported by the 2013 scientific promotion program funded by Jeju National University."
"This study was presented at 3rd World Congress of Thoracic Imaging in Seoul, Korea in June, 2013."

of the radiographic appearance is the integrity of the host's immune response[3,8,19]. Severely immunocompromised patients show a tendency to have the primary form of TB-lymphadenopathy, whereas immunocompetent patients tend to have the postprimary form-parenchymal granulomatous inflammation with slowly progressive nodularity and cavitation[8].

The radiographic findings cannot be simply devided into primary and postprimary forms of TB, and the traditional classification of TB into primary and postprimary should be avoided.

In this regard, we need to use the accurate descriptive terminology, instead of using the inappropriate previous terminologies (primary and reactivation TB). We suggest a radiological classification of chest TB as follows;

- Parehchymal TB
  - Air-space consolidation
  - Focal nodular lesion and linear density
  - Cavity
  - Tuberculoma
  - Fibrosis, scar, and destruction
- Tracheobronchial TB
- Miliary TB
- Lymph node TB
- Pleural and chest wall TB
- Pericardial TB

Radiological Classification and Illustration of Chest Tuberculosis

1. Parenchymal TB

1) Air-space consolidation

It is related to parenchymal granulomatous inflammation[3]. Particularly in patients with impaired T-cell function, coalescence and enlargement of multiple foci of such inflammation lead to extensive consolidation. In immunocompetent patients, focal or patchy consolidation with surrounding nodules may be seen in the upper lobes and the superior segments of the lower lobes[7].(Fig. 1 & Fig. 2)

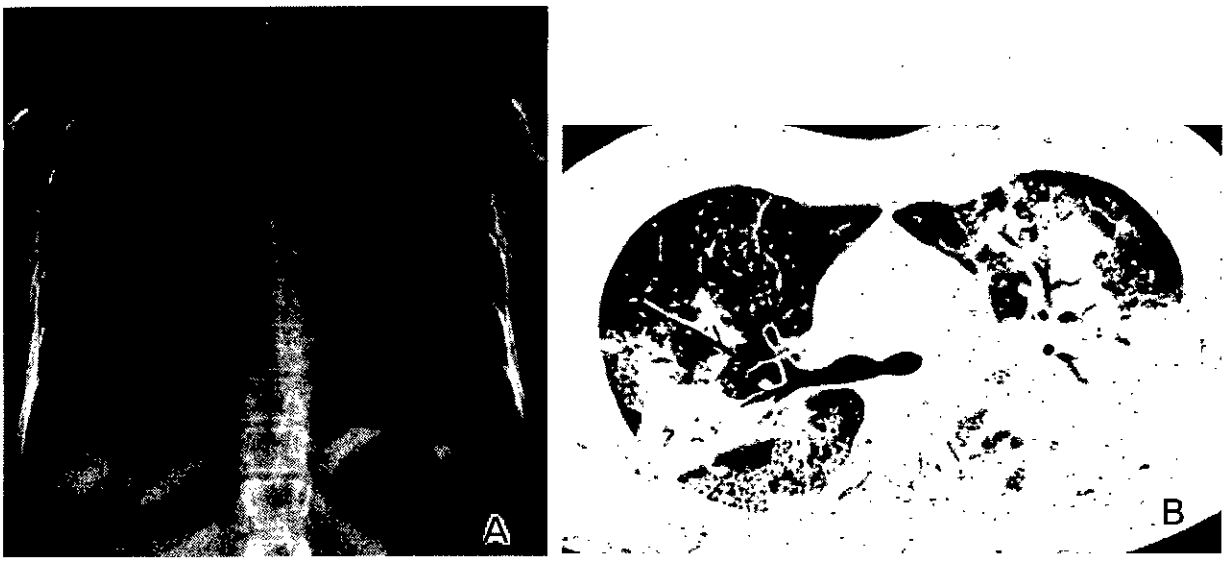

Figure 1. Pulmonary tuberculosis in a 24-year-old woman.
Chest radiograph(A) and high-resolution CT scan(B) show extensive air-space consolidation in both upper lung zones.

2) Focal nodular lesion and linear density

The centrilobular nodules and branching linear/ nodular opacities (tree-in-bud pattern) are due to the presence of caseation necrosis and granulomatous inflammation within and surrounding the terminal and respiratory bronchioles and alveolar ducts[8,14,15](fig.3). Coalescence or clustering of small nodules lead to the formation of a large nodule (so-called galaxy sign[8](fig.4).

3) Cavity

With erosion into airways and subsequent evacuation of necrotic materials, a cavity can be formed within a parenchymal lesion (Fig. 5). The expulsed necrotic material frequently spreads via the bronchi to other parts of the lung (endobronchial spread)[7]. Therefore, cavitation is an important sign of an active disease.

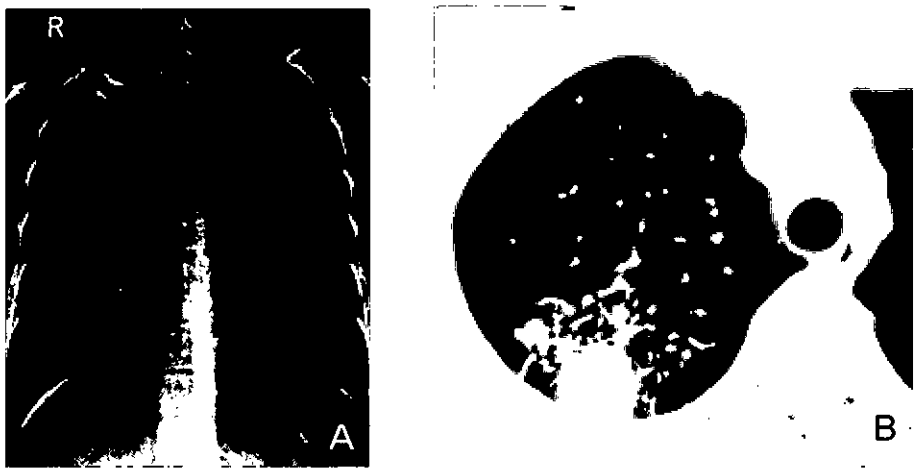

Figure 2. Pulmonary tuberculosis in a 35-year-old woman.
Chest radiograph(A) and high-resolution CT scan(B) show focal consolidation and surrounding small nodular lesions in the right upper lobe.

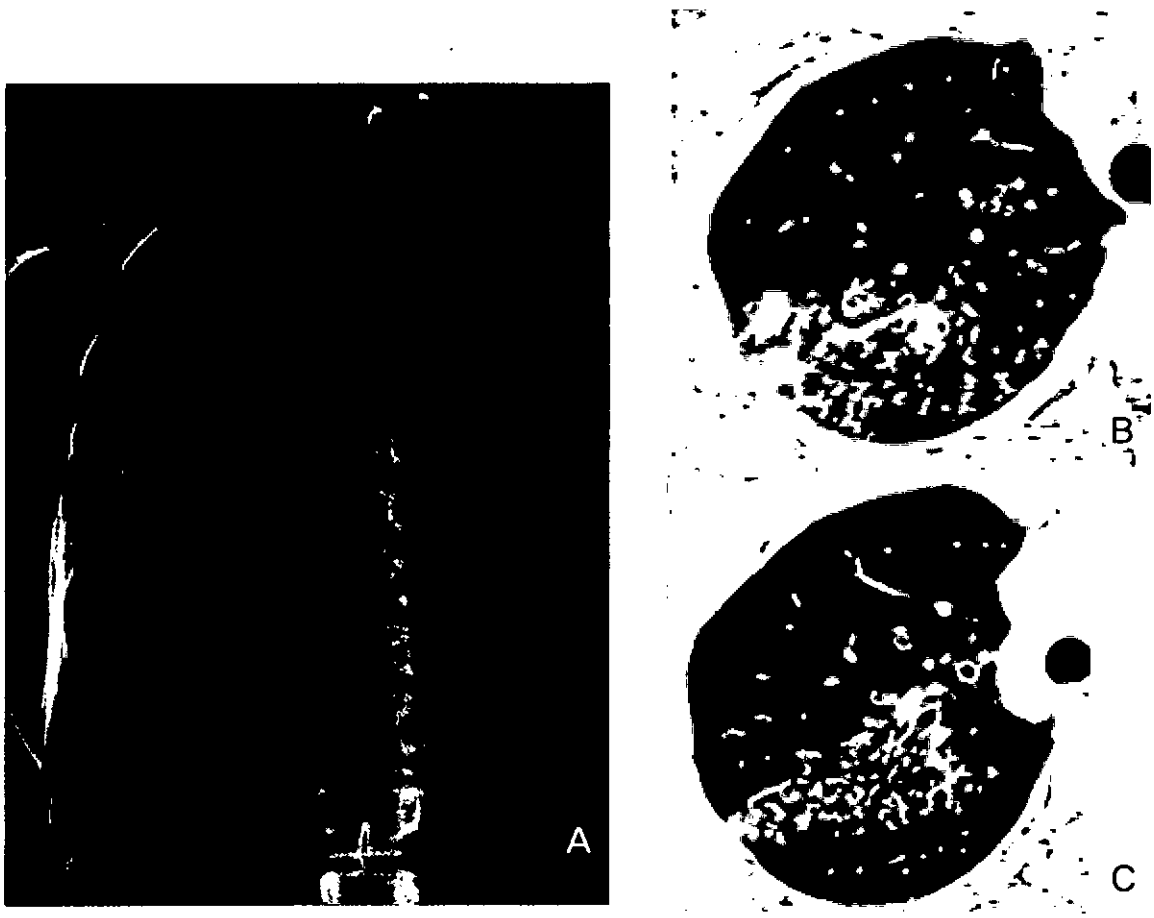

Figure 3. Pulmonary tuberculosis presenting with small nodules and branching linear structures in a 24-year-old woman.
A. Targeted view of chest radiograph shows peribronchial small nodular lesions and focal consolidation in the right upper lobe.
B-C. Lung window images of transverse high-resolution CT(1.0-mm section thickness) scans obtained at levels of trachea (B) and carina (C) demonstrate branching linear structures and small nodules (tree-in-bud sign), and lobular consolidation in the posterior segment of rightupper lobe.

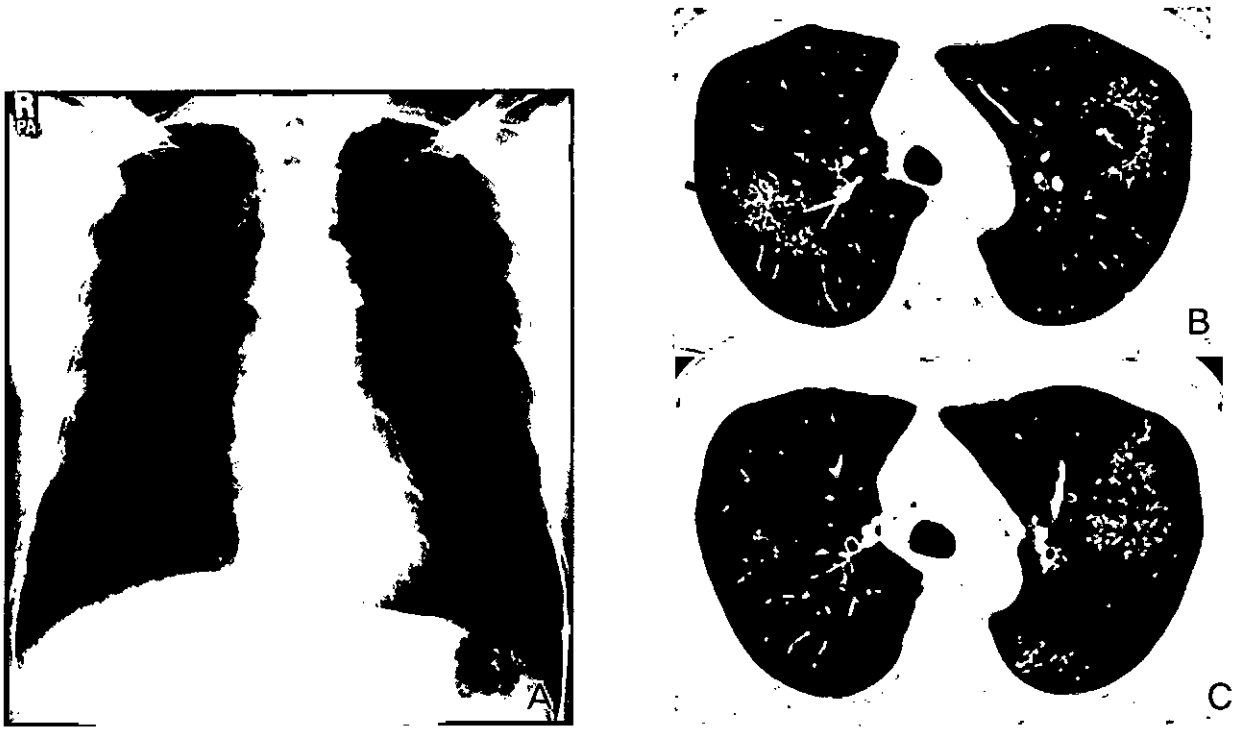

Figure 4. Pulmonary tuberculosis showing CT galaxy sign in a 53-year-old man.
A. Chest radiograph shows fine reticulonodular opacities in bilateral upper lung zones.
B & C. Lung window images of transverse high-resolution CT scans (1.0-mm section thickness) obtained at levels of aortic arch (B) and azygos arch (C), respectively, demonstrate lung lesions consisting of small centrilobular nodules and branching linear structures (arrows; forming so-called galaxy sign) in both upper lobes. Similar lesions are observed in superior segment of left lower lobe.

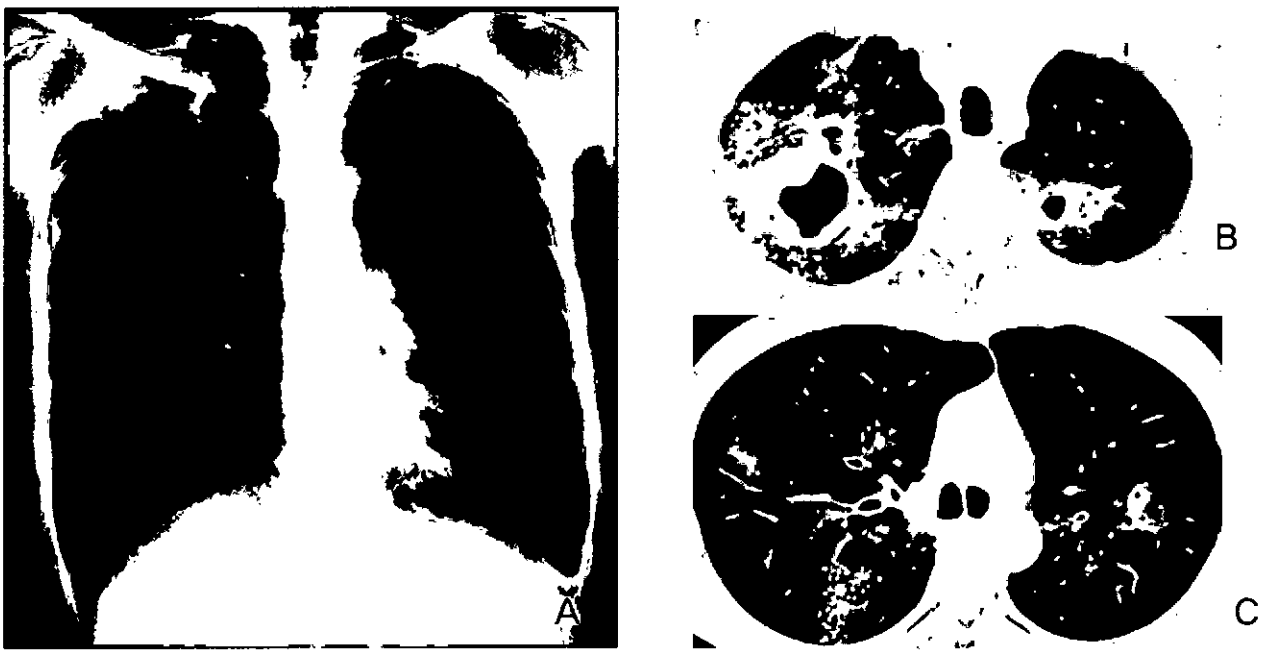

Figure 5. Active pulmonary tuberculosis with cavity in a 44-year-old man.
A. Chest radiograph shows cavitary lesion in the right upper lung zone and nodular opacities in bilateral upper lung zones. B. Lung window image of transverse high-resolution CT scans (1.0-mm section thickness) obtained at level of great vessels demonstrates cavitary lesions in both upper lobes. C. Lung window image of transverse high-resolution CT scans (1.0-mm section thickness) obtained at level of subcarina demonstrates cavitary nodules in the left upper lobe and dense lobular consolidation and tree-in-bud signs in the right upper lobe.

4) Tuberculoma

"Tuberculoma" refers to a well-delimited, round or oval focus of parenchymal TB[16]. Tuberculomas may show central necrosis, cavitation, and satellite nodules (Fig. 6). On CT, following intravenous administration of contrast, tuberculomas often show ring-like enhancement. Ring-like enhancement corresponds histologically to the granulomatous inflammatory tissue capsule, whereas the nonenhancing area corresponds to the central necrotic material[7]. Only calcified lesions should be considered inactive[17].

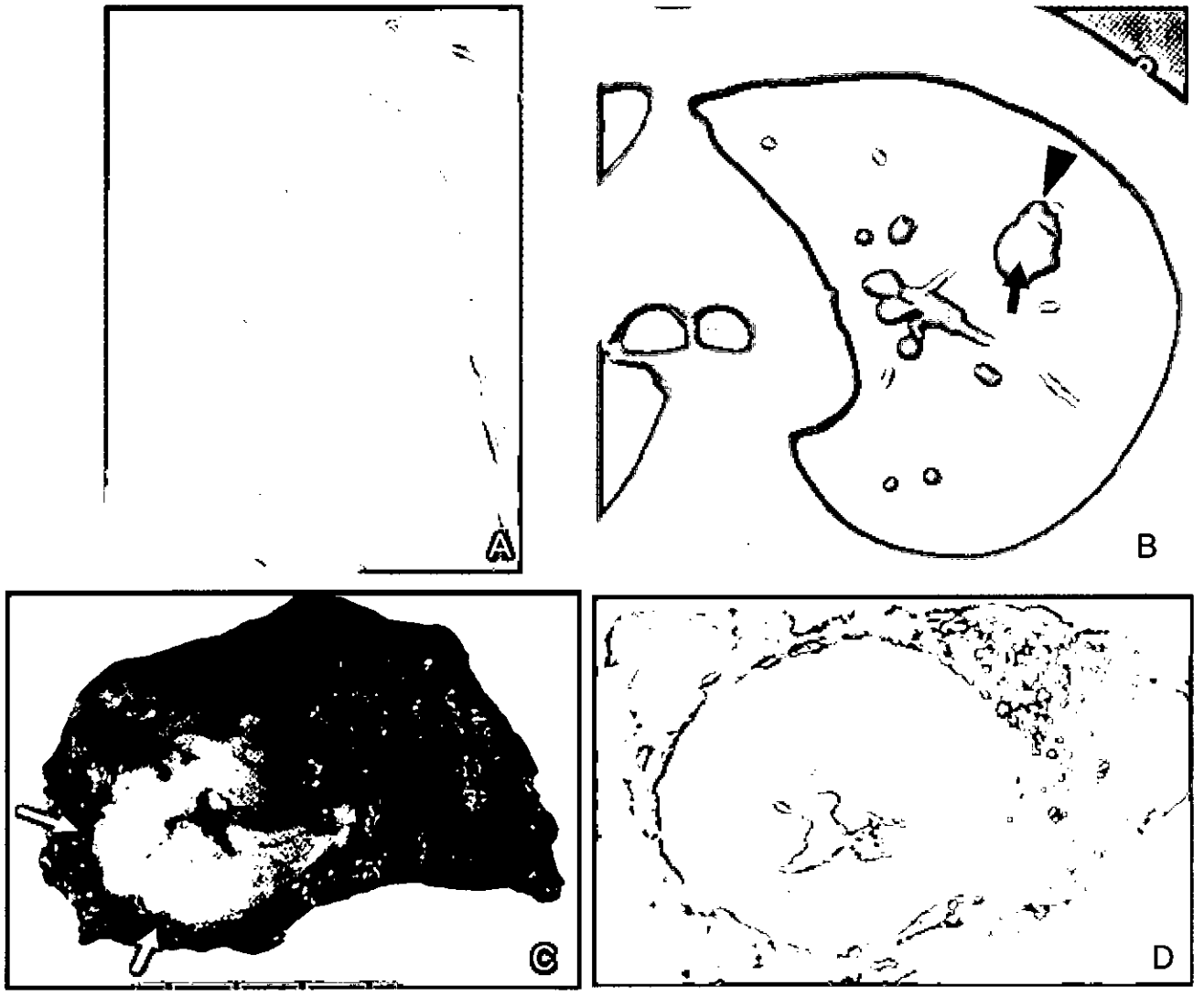

Figure 6. Tuberculoma in a 41-year-old man. (Courtesy: Kyoung Soo Lee, MD, of Samsung Medical Center, Seoul, Korea)
A. Chest radiograph shows an oval nodule in left upper lung zone. B. Lung window image of transverse CT scan (5.0-mm section thickness) obtained at level of main bronchi demonstrates a nodule containing central cavitation (arrow). Also note surrounding satellite nodule (arrowhead). C. Photograph of surgical resection specimen demonstrates nodule consisting of central coseation necrosis (tan yellow area) and surrounding collageneous connective fibrous capsule (arrows). D. Low-magnification photomicrograph reveals typical tuberculoma composed of well-defined central focus of necrosis and surrounding inflammatory and fibrous capsule.

5) Fibrosis, scar, and destruction

Healing of parenchymal TB is associated with more marked fibrosis and calcification[7](Fig.7). Cicatrization atelectasis is common after cavitary disease, and manifests as atelectasis of the upper lobe, retraction of the hilum, compensatory lower lobe hyperinflation, and mediastinal shift toward the fibrotic lung[18]. Apical pleural thickening associated with fibrosis may reveal proliferation of extrapleural fatty tissue and peripheral atelectasis on CT[19]. Complete destruction of a whole lung or a major part of a lung is not uncommon in the end stages of tuberculosis. Such damage results from a combination of parenchymal and airway involvement[18](Fig.8).

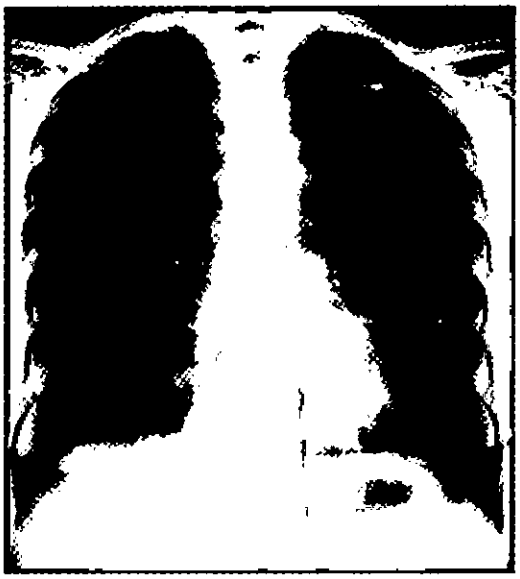

Figure 7. Healed TB lesion in a 38-year-old woman.
Chest radiograph shows multiple parenchymal calcifications and linear fibrotic bands in the left upper lung zone.

Figure 8. Chronic destructive TB lesion mainly involving right upper lobe in a 70-year-old man.
A. Chest radiograph shows marked volume decrease in right upper lung zone with upward elevation of the right hilum and tracheal deviation. Note the right apical pleural thickening and right costophrenic angle blunting. Focal pleural thickening in the left apex and several nodular opacities in the left upper lung zone are also noted. B. Lung window image of transverse high-resolution CT scan (1.0-mm section thickness) obtained at level of great vessels demonstrates traction bronchiectasis with volume decrease in the right upper lobe.
C. Coronal reformatted CT scan (2.0-mm section thickness) demonstrates extrapleural fat proliferation in the right apex.

2. Tracheobronchial TB

Tracheobronchial TB has been reported in 10-20% of patients with pulmonary TB. Long segmental circumferential wall thickening and luminal narrowing of the central airways can be seen in both active and fibrotic stages. However, in patients with active disease, CT scans show irregular and thick-walled airways, a pattern that is reversible (Fig. 9), whereas patients with fibrotic disease generally had smooth narrowing of airways and minimal wall thickening, a pattern that is not reversible[20](Fig.10).

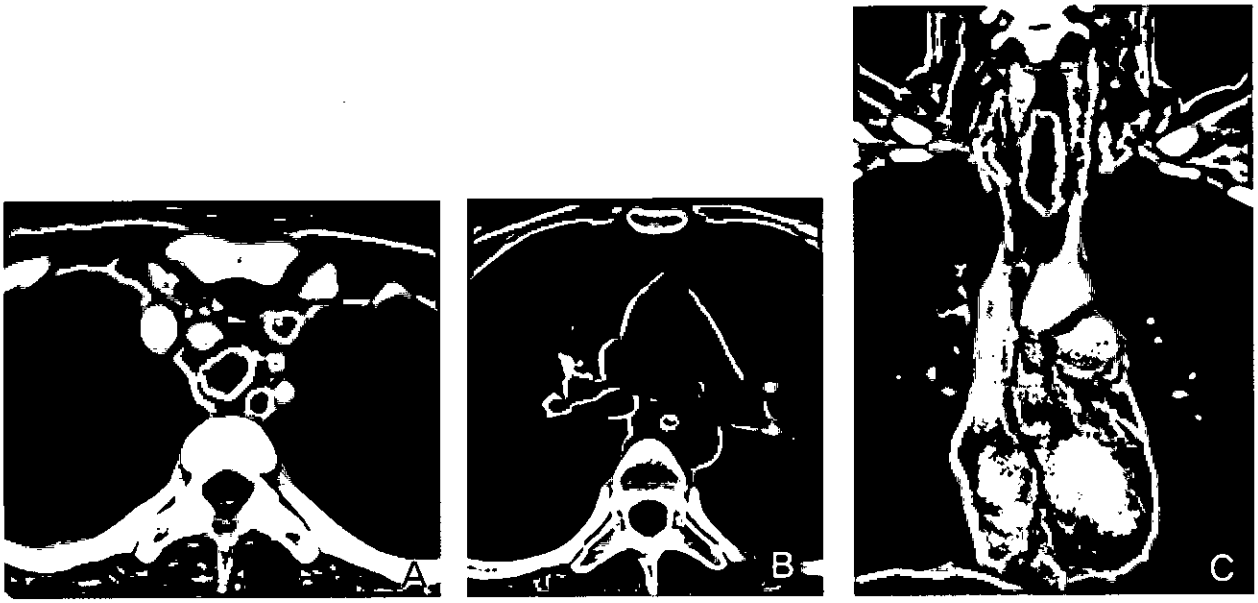

Figure 9. Active stage of trachea-bronchial TB in an 18-year-old girl.
A & B. Mediastinal window images of transverse enhanced CT scans (2.5-mm section thickness) obtained at levels of great vessels (A) and main bronchi (B), respectively, demonstrate irregular wall thickening in distal trachea and right main bronchus.
C. Coronal reformatted mediastinal window image demonstrates irregular wall thickening in distal trachea.

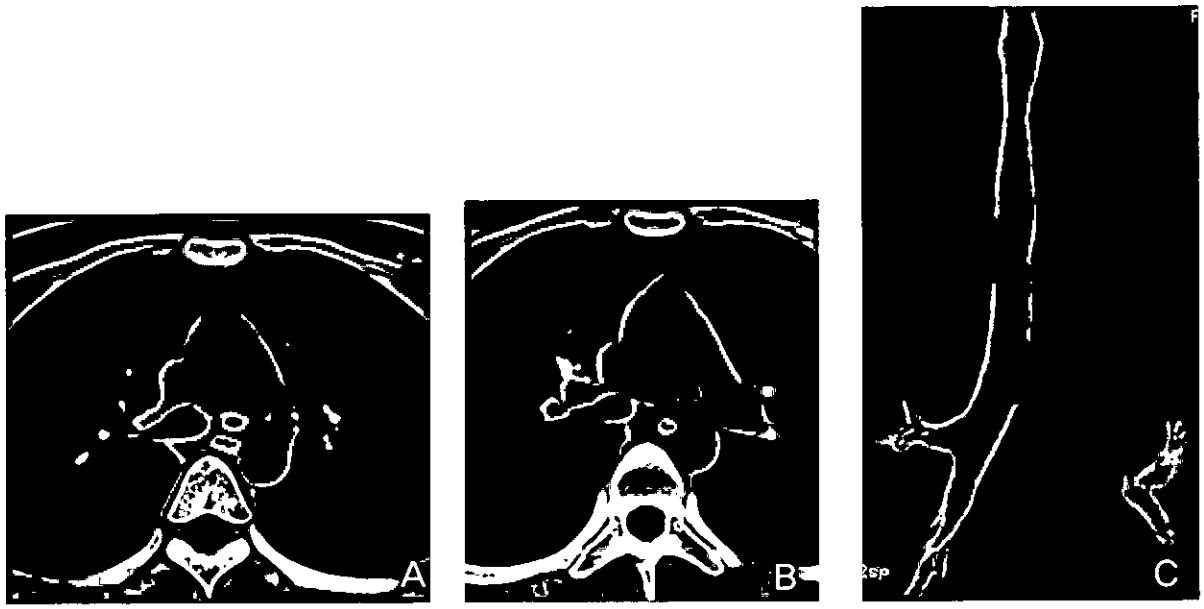

Figure 10. Fibrotic stage of bronchial TB involving left main bronchus in a 23-year-old woman.
A & B. Mediastinal window images of transverse unenhanced CT scans (2.5-mm section thickness) obtained at levels of main bronchi (A) and right upper lobar bronchus (B), respectively, demonstrate concentric wall thickening of left main bronchus. Also note obliterated bronchial lumen in distal portion of left main bronchus. C. 3D volume-rendering image discloses marked luminal narrowing and obliteration of left main bronchus.

3. Miliary TB

Miliary TB refers to widespread dissemination of TB by hematogenous spread. The characteristic radiographic and high-resolution CT findings consist of innumerable, 1- to 3-mm diameter nodules randomly distributed throughout both lungs[3,7](Fig.11).

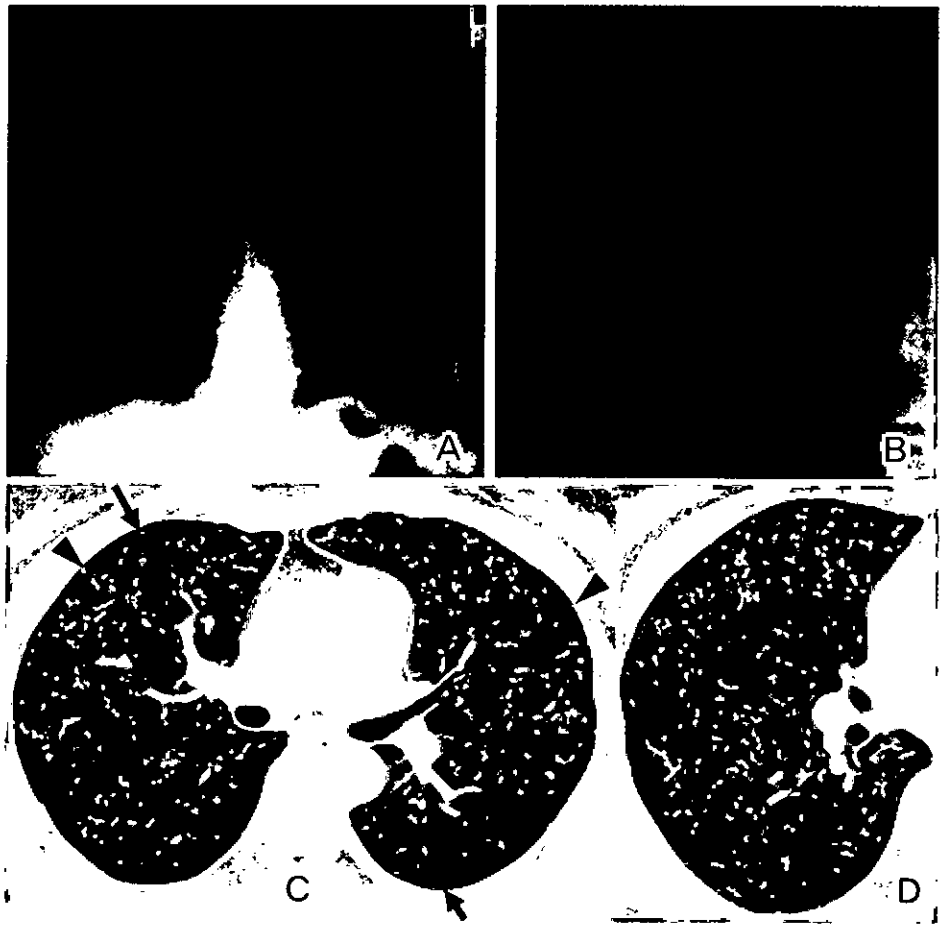

Figure 11. Miliary TB in a 40-year-old woman.
A. Chest radiograph shows diffuse granular or ground-glass opacity in both lungs. B. Targeted view of chest radiograph shows more clear small nodules of 2-3 mm in diameter, miliary nodules. C & D. Lung window images of transverse high-resolution CT scans (1.0-mm section thickness) obtained at level of bronchus intermedius (C) and targeted view obtained at level of right middle lobar bronchus (D) demonstrate miliary nodules of random distribution: nodules distributed in centrilobular ocation (arrows), along pleura (arrowheads), and along fissure (curved arrows).

4. Lymph node TB

During the stage of active disease, TB organisms frequently spread to the regional lymph nodes, where the ensuing granulomatous inflammatory reaction results in lymph node enlargement. Thoracic lymphadenopathy is most commonly unilateral and located in the hilum or paratracheal region. On CT, the enlarged nodes frequently have low attenuation and show peripheral (rim) enhancement. The former corresponds to the central necrotic portion of the node, and the latter, to the surrounding inflammatory tissue[7,21](Fig.12). In TB infection, there is considerable difference in the prevalence of radiologic findings in infants and children compared with those in adults. The most common abnormality in infants and children consists of lymph node enlargement, which is seen in 90% to 95% of cases[7,22].

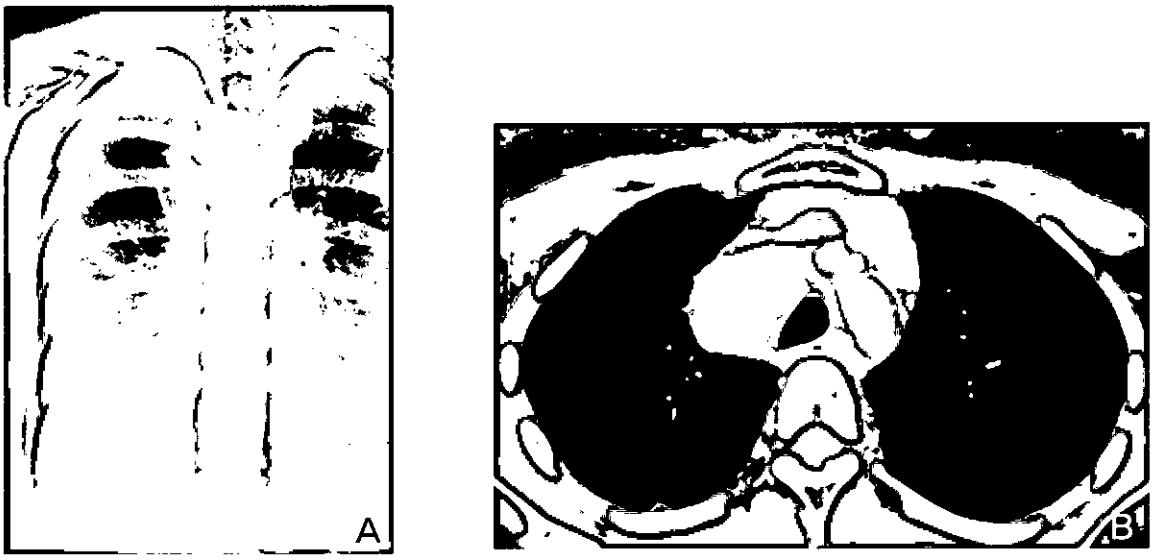

Figure 12. Tuberculous lymphadenitis in a 28-year-old woman.
A. Chest radiograph shows bilateral superior mediastinal widening.
B. Mediastinal window image of transverse enhanced CT scan (5-mm section thickness) demonstrates enlarged lymph nodes in the right upper paratracheal area and bilateral prevascular areas with central necrotic low attenuation and peripheral enhancing rim.

5. Pleural and chest wall TB

Pleural effusion, typically unilateral, occurs in 15-20% of TB patients[5,23]. Althogh pleural effusion is usually associated with parenchymal abnormalities, it may be the only radiologic manifestation of TB. Pleural effusion can be caused by rupture of a tuberculous cavity into the pleural space. This may result in the formation of tubercuous empyema and, occasionally, a bronchopleural fistula with pleural air-fluid level[5,18](Fig.13 & Fig.14). Empyema necessitatis result from leakage of TB empyema through the parietal pleura with discharge of its contents into the subcutaneous tissues of the chest wall[24](Fig.15).

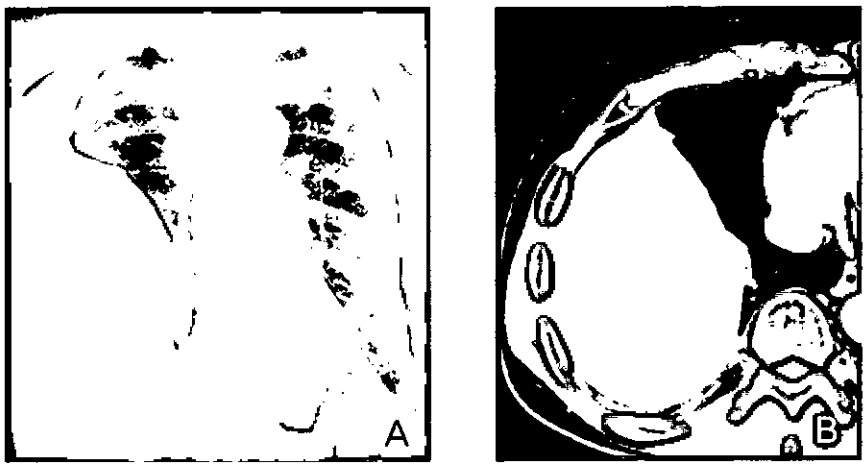

Figure 13. Loculated empyema in a 51-year-old man.
A. Chest radiograph shows moderate pleural effusion with convex border in the right hemithorax, representing empyema.
B. Mediastinal window image of transverse enhanced CT scan (2.0-mm section thickness) shows loculated pleural effusion with diffuse pleural thickening in the right hemithorax, representing empyema.

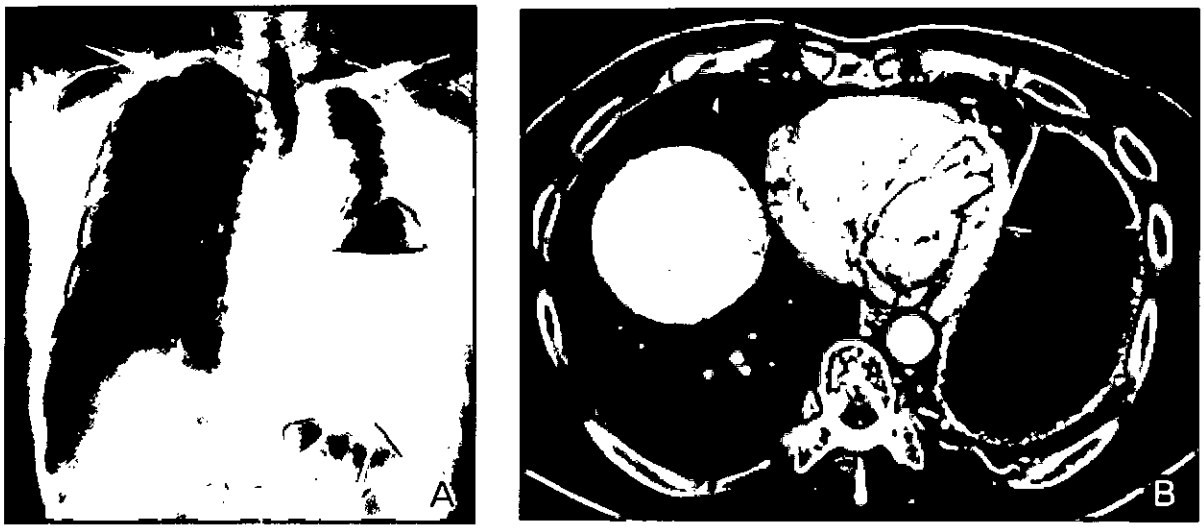

Figure 14. Bronchopleural fistula in a 62-year-old woman.
A. Chest radiograph shows air-fluid level in the left hemithorax, which suggests the possibility of bronchopleural fistula. Right upper lung zone shows multiple small peribronchial nodular opacities. Also note volume decrease with fibrocalcified parenchymal change in the left upper lung zone and circumferential pleural thickening or effusion in the left upper hemithorax. B. Mediastinal window image of transverse enhanced CT scan (2.0-mm section thickness) shows loculated pleural effusion with diffuse pleural thickening and air-fluid level in the left hemithorax, representing empyema with bronchopleural fistula.

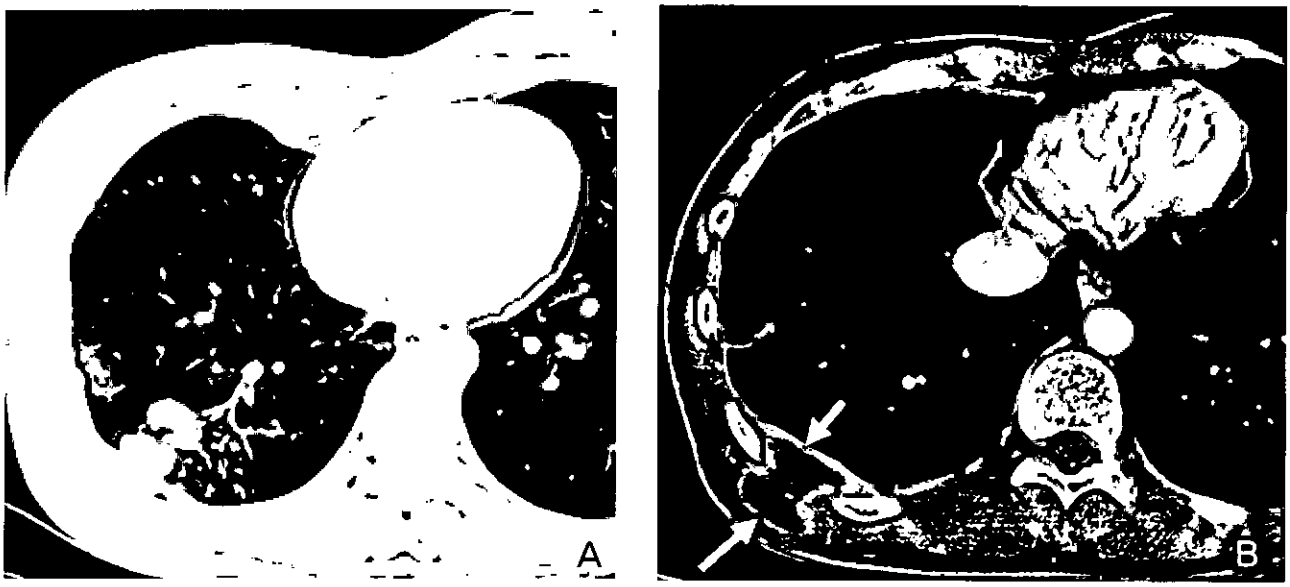

Figure 15. Empyema necessitatis in a 30-year-old woman.
A. Lung window images of transverse enhanced CT scan (5.0-mm section thickness) obtained at ventricular level demonstrates parenchymal tuberculous lesion, consisting of nodules and tree-in-bud signs, in right lower lobe.
B. Mediastinal window image of transverse enhanced CT scan (5.0-mm section thicknes) obtained at level of supra-hepatic inferior vena cava demonstrates low-attenuation lesion with rim enhancement (arrows) having both intrathoracic and chest wall components of disease (empyema necessitatis).

6. Pericardial TB

Tuberculous pericarditis develops secondary to contiguous spread from mediastinal nodes, lungs, spine, or sternum, or during miliary dissemination[25]. Pericardial TB presents as pericardial effusion, thickening, or calcification on CT scans[26](Fig.16).

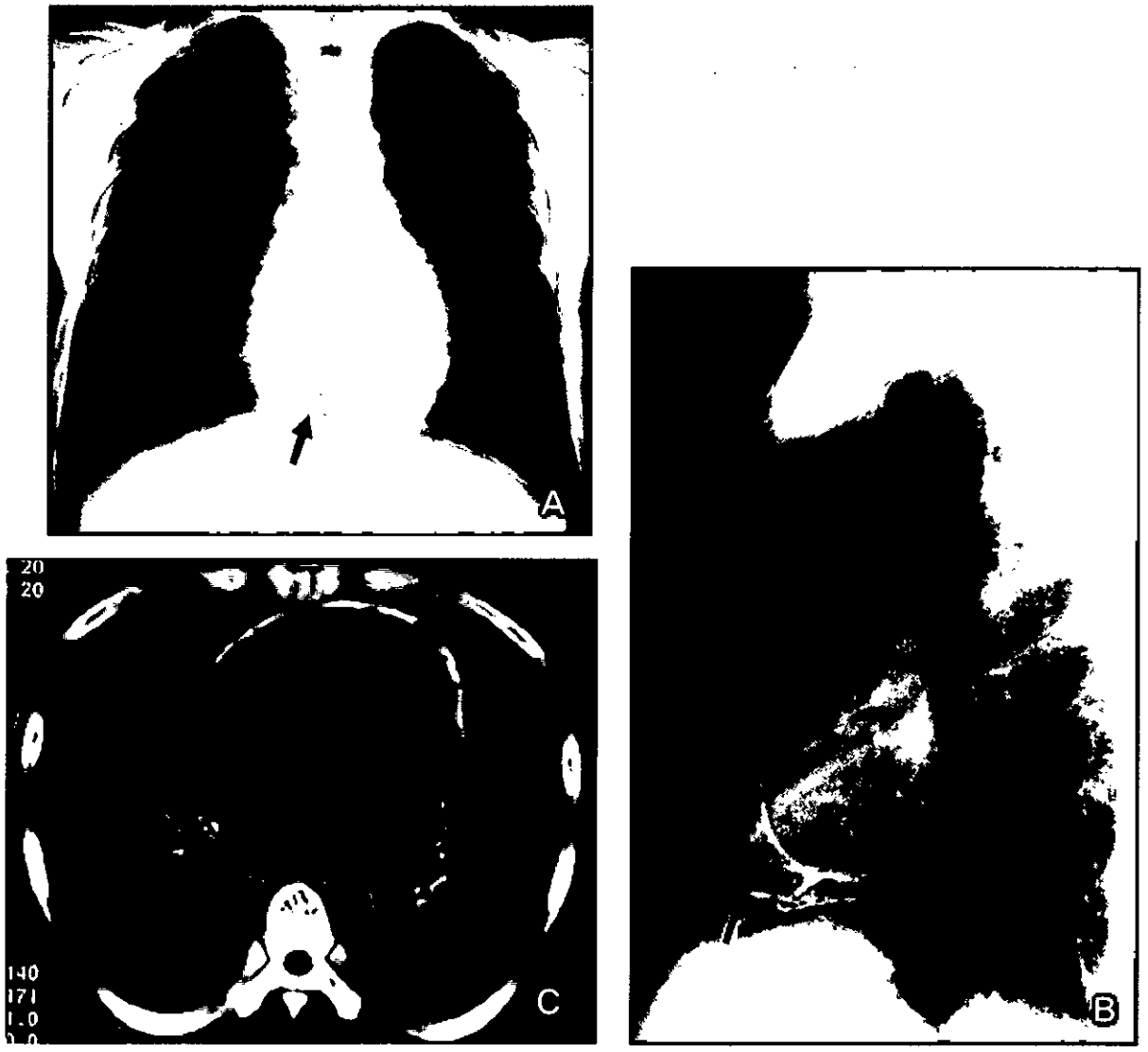

Figure 16. Constrictive pericarditis as a sequelae of tuberculous pericarditis.
A & B. Posteroanterior (A) and lateral (B) chest radiographs show thick pericardial calcification (arrows) along the anterior and diaphragmatic surface of theheart.
C. Nonenhanced transverse CT scan (5.0-mm section thickness) demonstrates circumferential pericardial calcification.

References

1) Cegielski JP, Chin DP, Espinal MA, et al. The global tuberculosis situation: progress and problems in the 20th century, prospects for the 21st century. *Infect Dis Clin N Am.* 2002; 16: 1-58
2) Corbett EL, Watt CJ, Walker N, et al. The growing burden of tuberculosis: global trends and interactions with the HIV epidemic. *Arch Intern med.* 2003; 163: 1009-1021
3) Jeong YJ, Lee KS. Pulmonary tuberculosis: up-to-date imaging and management. *Am J Roentgenol.* 2008; 191: 834-844
4) World Health Organization. Global tuberculosis report 2013. www.who.int/tb/publications/global_report/gtbr13_executive_summary.pdf. WHO website. Accessed on November 25, 2013
5) NL Muller, Franquet T, Lee KS. Imaging of pulmonary infections. Philadelphia, PA: Lippincott Williams & Wilkins, 2007
6) Lee KS, Im JG. CT in adults with tuberculosis of the chest: characteristic findings and role in management. *Am J Roentgenol.* 1995; 164: 1361-1367
7) Lee KS, Franquet T, Han J, Johkoh T. Muller's disease of the lung: Radiologic and Pathologic Correlations. 2nd ed. Philadelphia, PA: Lippincott Wiliams & Wilkins, 2012
8) NL Muller, CI Silva. Imaging of the chest - volume I. Philadelphia, PA: Saunders/Elsevier, 2008
9) Barnes PF, Cave MD. Molecular epidemiology of tuberculosis. N Engl J Med 2003; 349: 1149-1156
10) Small PM, Hopewell PC, Singh SP, et al. The epidemiology of tuberculosis in San Francisco: a population-based study using conventional and molecular methods. *N Engl J Med* 1994; 330: 1703-1709
11) Alland D, Kalkut GE, Moss AR, et al. Transmission of tuberculosis in New York City: an analysis by DNA fingerprinting and conventional epidemiologic methods. *N Engl J Med* 1994; 330: 1710-1716
12) Jones BE, Ryu R, Yang Z, et al. Chest radiographic findings in patients with tuberculosis with recent or remote infection. *Am J Respir Crit Care Med* 1997; 156: 1270-1273
13) Geng E, Kreiswirth B, Burzynski J, et al. Clinical and radiographic correlates of primary and reactivation tuberculosis: a molecular epidemiology study. *JAMA* 2005; 293: 2740-2745
14) Im JG, Itoh H, Lee KS, et al. CT-pathology correlation of pulmonary tuberculosis. *Crit Rev Diagn Imaging* 1995; 36: 227-285
15) Lee JY, Lee KS, Jung KJ, et al. Pulmonary tuberculosis: CT and pathologic correlation. *J Comput Assist Tomogr* 2000; 24: 691-698
16) Murayama S, Murakami J, Hashimoto S, et al. Noncalcified pulmonary tuberculomas: CT enhancement patterns with histological correlation. *J Thorac imaging* 1995; 10: 91-95
17) Andronikou S, Vanhoenacker FM, De Backer AI, et al. Advances in Imaging Chest Tuberculosis: Blurring of Differences Between Children and Adults. *Clin Chest Med.* 2009 Dec; 30(4): 717-744
18) Kim HY, Song KS, Goo JM, et al. Thoracic sequelae and complications of tuberculosis. *Radiographics* 2001; 21(4): 839-858
19) Im JG, Webb WR, Han MC, et al. Apical opacity associated with pulmonary tuberculosis: high-resolution CT findings. *Radiology* 1991; 178: 727-731
20) Moon WK, Im JG, Yeon KM, et al. Tuberculosis of the central airways: CT findings of active and fibrotic disease. *Am J Roentgenol.* 1997; 169: 649-653
21) Im JG, Song KS, Kang HS, et at. Mediastinal tuberculous lymphadenitis: CT manifestations. *Radiology* 1987; 164: 115-119
22) Leung AN, Muller NL, Pineda PR, et al. Primary tuberculosis in childhood: radiographic manifestations. *Radiology* 1992; 182: 87-91
23) Ebstein DM, Kline LR, Albelda SM, et al. Tuberculous pleural effusions. *Chest.* 1987; 91: 106-109
24) Choi JY, Hong KT, Oh YW, et al. CT manifestations of late sequelae in patients with tuberculous pleuritis. *Am J Roentgenol.* 2001; 176: 441-445
25) Golden MP, Vikram HR. Extrapulmonary tuberculosis: an overview. *Am Fam Physician* 2005; 72: 1761-8
26) Mayosi BM, Burgess LJ, Doubell AF. Tuberculous pericarditis. *Circulation* 2005; 112: 3608-16