Pulmonary Tuberculosis in Infants: Radiographic and CT Findings

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OBJECTIVE. As complications of tuberculosis are frequent in infancy, correct diagnosis of tuberculosis in infants is important. The purposes of this study are to summarize radiographic and CT findings of pulmonary tuberculosis in infants and to determine the radiologic features frequently seen in infants with this disease.

CONCLUSION. Frequent radiologic findings of pulmonary tuberculosis in infants are mediastinal or hilar lymphadenopathy with central necrosis and air-space consolidations, especially masslike consolidations with low-attenuation areas or cavities within the consolidation. Disseminated pulmonary nodules and airway complications are also frequently detected in this age group. CT is a useful diagnostic technique in infants with tuberculosis because it can show parenchymal lesions and tuberculous lymphadenopathy better than chest radiography. CT scans can also be helpful when chest radiographs are inconclusive or complications of tuberculosis are suspected.

Keywords: chest, CT, infant/neonate, primary tuberculosis, chest radiography, tuberculosis

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Tuberculosis remains an important cause of morbidity and mortality worldwide. Mainly as a result of the worsening HIV epidemic, homelessness, drug abuse, and immigration from developing countries, the problem of pulmonary tuberculosis in Western countries has markedly increased [1–4]. Children represent one of the high-risk groups in the resurgence of this disease [5–7]. Among children, those younger than 5 years are at the highest risk for pulmonary tuberculosis [2].

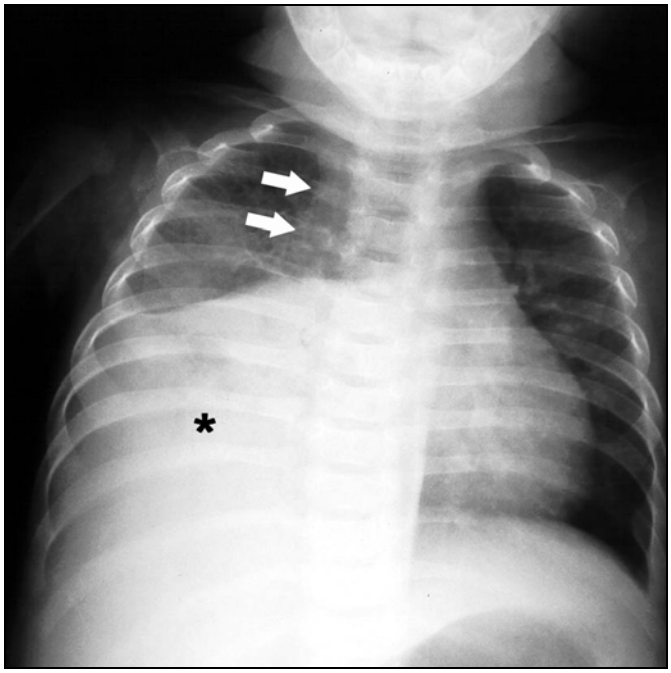
Pulmonary tuberculosis in infants has some differences from that seen in older children; it is more symptomatic, and the risk of severe and life-threatening complications such as tuberculous meningitis or miliary tuberculosis is higher [7–9]. Therefore, early diagnosis and prompt treatment are very important for infants with tuberculosis. Bacteriologic confirmation of the disease in children is difficult [5, 10, 11], and in younger infants (< 3 months), the tuberculin skin test is frequently negative [8–11]. Therefore, chest radiographs and a history of direct contact with patients who have contagious tuberculosis play essential roles in diagnosing tuberculosis in infants. The importance of the role of radiologists cannot be overemphasized.

CT scans have advantages over conventional radiographs in diagnosing tuberculosis in pediatric patients and can detect the disease in patients whose chest radiographs are normal or equivocal. CT scans can reveal lymphadenopathy; calcifications; bronchogenic nodules; and complications such as airway narrowing, emphysema, and pleural effusion [12–17]. High-resolution CT may depict miliary nodules or bronchogenic nodules in the lung parenchyma, especially in patients with no evidence of nodules on the chest radiograph [17, 18]. Although a few studies have reported chest radiographic findings of infant tuberculosis [7–9], CT findings of the disease have been reported only sporadically [16, 19]. The purposes of this study are to summarize radiographic and CT findings of pulmonary tuberculosis in infants and identify the frequent radiologic findings of pulmonary tuberculosis in infants.

Materials and Methods

We retrospectively reviewed chest radiographs (n = 25) and chest CT scans (n = 17) of 25 consecutive infants who were diagnosed with pulmonary tuberculosis in our institution from 1991 to 2003. The diagnosis of tuberculosis was established by positive culture or staining of gastric aspirates for acid-fast bacilli in four patients, positive results of polymerase chain reaction for *Mycobacterium tuberculosis* in five patients, positive culture of ascites for *M. tuberculosis* in one, and surgical

Fig. 1—4-month-old girl with pulmonary tuberculosis (patient 15). Masslike consolidation and bronchial obstruction caused by hilar lymphadenopathy.
A, Chest radiograph shows consolidation in right lower lung zone (*asterisk*) and widening of right upper mediastinum (*arrows*).
B, Enhanced CT scan shows well-defined, well-enhancing, masslike consolidation in right lower lobe (*asterisk*). Note low-attenuation lymphadenopathy (*arrow*) obstructing bronchus intermedius.
C, CT scan in lower level of image seen in **B** shows large consolidation in right middle lobe and right lower lobe. Consolidation is slightly volume expanding. There are multiple low-attenuation areas (*arrows*) in consolidation area.



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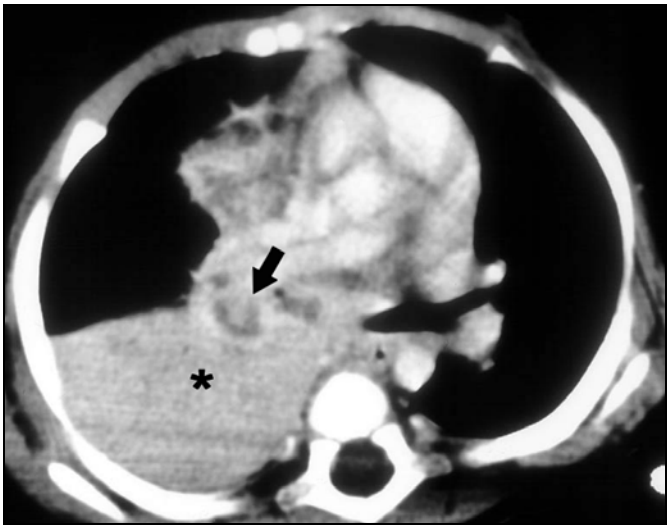

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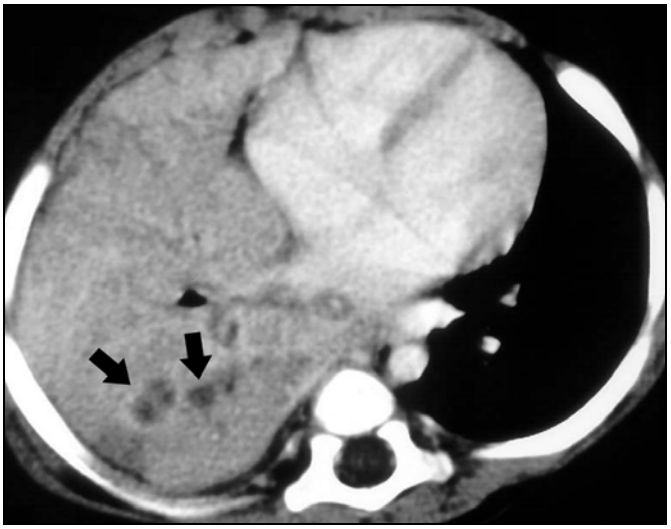

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biopsy in one. In the remaining 14 patients, more than two of the following three criteria were met [20]: tuberculin skin test (Mantoux test) with five tuberculin units of purified protein derivative that resulted in an area of induration of 10 mm or greater; ruling out other causes of disease and finding that subsequent clinical course of the disease was consistent with tuberculosis (clinical or radiologic improvement from antituberculous medications); and discovery of at least one family member with contagious tuberculosis.

The study group included 15 boys and 10 girls ranging in age from 2 to 12 months (mean age, 5.9 months). None of the children were immunocompromised, and none were HIV positive. Twenty-one patients were vaccinated with BCG (bacille Calmette-Guérin) at the age of 4 weeks. Physical examination of the BCG site and the regional lymph nodes revealed no abnormalities. The Mantoux test was performed in all patients and showed positive results in 11 (44%). Seven patients (28%) were exposed to household members with active pulmonary tuberculosis. Symptoms of the patients were fever (84%), cough (76%), sputum (48%), rhinorrhea (36%), and tachypnea (32%). In two patients, seizure was an initial manifestation with no significant respiratory symptoms. Systemic dissemination was discovered in eight patients (32%) as follows: brain (n = 4), liver (n = 2), spleen (n = 3), and kidney (n = 1). The median duration of symptoms before the diagnosis of tuberculosis and start of antituberculous medication was 50 days (range, 1–90 days). In four infants (16%), the duration of symptoms was less than 1 week.

Initial chest radiographs were available in all patients. Follow-up chest radiographs were available in 23 patients. The radiographic follow-up was not uniform in all patients, and the mean follow-up duration was 2 years (range, 4 months to 3.5 years).

Chest CT scans were performed 1–10 days (mean, 4 days) after initial chest radiography for one or more of the following reasons: to evaluate

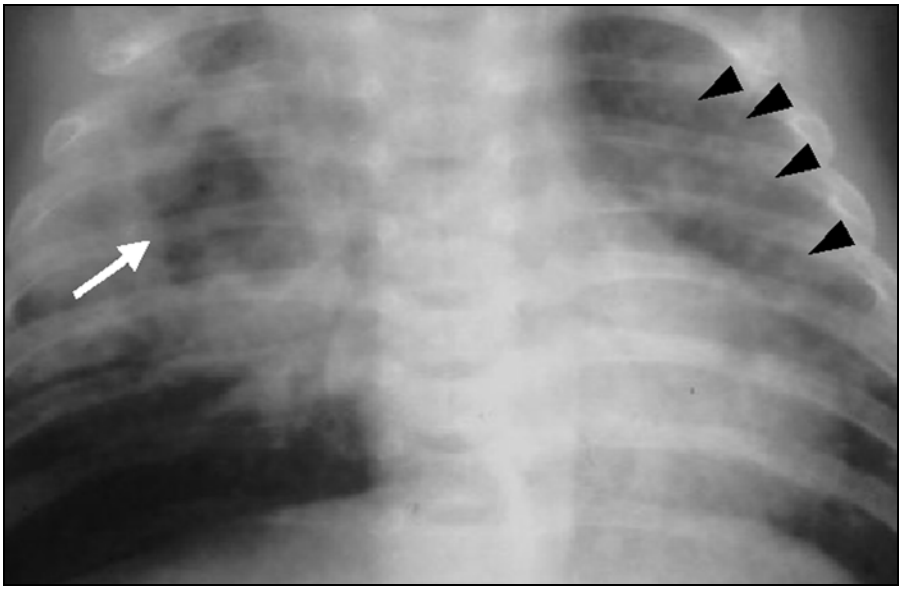


Fig. 2—6-month-old boy with pulmonary tuberculosis (patient 10). Large cavity within consolidation. Chest radiograph shows large cavity within consolidation in right upper lobe (*arrow*). Multiple nodules are seen in left upper lung field (*arrowheads*).

unusual findings on radiographs such as masslike lesions or widespread nodules; to find or confirm lymphadenopathy; and to detect or evaluate complications such as airway narrowing with or without atelectasis or emphysema, or pleural or pericardial tuberculosis.

CT scans were obtained with third-generation CT scanners—CT/T 9800 scanner or a HiSpeed Advantage System (both manufactured by GE Healthcare)—at 40–100 mA, 120 kVp, and 1–2 seconds of scanning time. CT scans were obtained after IV bolus injection of contrast media, with contiguous 5–10-mm-thick sections from the lung apex to the diaphragm. In three patients, supplementary high-resolution CT scans with 1.5-mm-thick sections were obtained at 5–10-mm intervals with an edge-enhancing algorithm.

Three radiologists analyzed the chest radiographs and CT scans by consensus. In the chest radiographs, particular attention was given to the pattern of pulmonary parenchymal lesions (consolidation, nodules, and disseminated disease), cavities within parenchymal lesions, mediastinal bulging suggesting lymphadenopathy, and airway or pleural complications. On the CT scans, patterns of pulmonary parenchymal lesions (air-space consolidation, bronchogenic nodules, and disseminated nodules); cavities within parenchymal lesions; mediastinal and hilar lymphadenopathy with or without central necrosis; airway complications; pleural, pericardial, and chest wall lesions; and involvement of other organs were observed carefully. When we found a consolidation during the reviewing process, which was enhancing well after contrast agent administration, was volume preserving or expanding, and had no air-bronchogram within it, we defined it as a "masslike consolidation."

Results

Chest Radiography

On chest radiography ($n = 25$), air-space consolidation was the most common parenchymal lesion, occurring in 20 patients (80%) (Fig. 1A). Nodular lesions were found in seven patients (28%), and, among them, ipsilateral or contralateral air-space consolidation was seen in five patients (Fig. 2). Disseminated nodules were found in six patients (24%) (Figs. 3A, 4A, and 5A), and all of them were 4 months old or younger. Cavitations within parenchymal lesions were noted in two patients (Figs. 2 and 4A).

Mediastinal bulging, suggesting mediastinal or hilar lymphadenopathy, was seen in 18 patients (72%) (Fig. 1A), but discerning the difference between a pulmonary parenchymal lesion near the hilum and lymphadenopathy was difficult on chest radiographs in many cases. Hyperinflation of the lung ($n = 8$, 32%) (Fig. 6A), bronchial narrowing ($n = 4$, 16%) (Fig. 6A), and atelectasis ($n = 4$, 16%) were also frequent findings. We found pleural effusion in one patient.

CT

On chest CT scans ($n = 17$), air-space consolidation was seen in all 17 patients. Masslike consolidation was seen in 10 of 17 patients (59%) (Figs. 1B, 1C, and 3C). The multifocal low-attenuation areas within the consolidation were seen in seven patients (41%) (Figs. 1C and 3C). Cavities within the consolidation were observed in five patients (29%). In one patient with a necrotic cavity within the consolidation, the necrotic cavity progressed to extensive bilateral bullous lesions; he was the only patient who did not survive. Disseminated pulmonary nodules were revealed in five patients (29%) (Figs. 3B, 4B, and 5B). In three of them, disseminated nodules were larger (> 2 mm in diameter) than the usual miliary nodules of adult tuberculosis and coalesced with each other (Figs. 3B and 4B). In one patient, cavities were seen within disseminated nodules (Fig. 4B). Bronchogenic nodules were found in seven patients (41%). In all three patients who had high-resolution CT, centrilobular nodules or branching linear structures suggesting bronchogenic spread of tuberculosis were seen (Fig. 6B). Excluding patients with disseminated nodules in both lungs, pulmonary parenchymal lesions were bilateral in six patients (50%) and involved the right upper lobe ($n = 10$), left upper lobe ($n = 9$), left lower lobe ($n = 7$), right lower lobe ($n = 7$), and right middle lobe ($n = 5$).

Mediastinal and hilar lymphadenopathies were observed in all 17 patients. On enhanced CT, involved lymph nodes showed central low attenuation and peripheral enhancement in all patients (Figs. 1B and 6C). The right paratracheal and subcarinal nodes were the most frequently involved (for both, $n = 13$, 76%). Lymphadenopathies of right hilar nodes were seen in 10 of 17 patients (59%), left paratracheal nodes were found in nine patients (53%), and left hilar nodes were found in seven (41%). In two patients (12%), calcifications were seen within the enlarged nodes.

Airway complications were also frequent findings on CT scans. Bronchial narrowing was seen in 11 patients (65%) who had adjacent peribronchial lymphadenopathy (Figs. 6C and 6D). Hyperinflation of the lung with mediastinal lymphadenopathy was seen in eight patients (47%) (Fig. 6B). Bronchiectasis was found in one patient.

Pleural effusions associated with air-space consolidation were seen in five patients (29%), and it was bilateral in one of them. Pleural effusion was loculated in one patient. Pericardial thickening was detected in two patients.

Chest radiography and CT findings are summarized in Table 1.

Additional Information at CT

In all 17 patients who had a CT scan, we acquired additional information that could not be obtained at chest radiography: revelation of mediastinal lymphadenopathy ($n = 4$), confirmation of lymphadenopathy ($n = 13$), depiction of central necrosis ($n = 17$) or calcification ($n = 2$) within the enlarged lymph nodes, detection of bronchial stenosis distal to the lobar bronchus ($n = 7$), revelation of pleural involvement ($n = 4$) and pericardial thickening ($n = 2$), and detection of extrathoracic lesions ($n = 3$). In four patients (24%), a diagnosis of tuberculosis was suggested only after a CT scan revealed enlarged lymph nodes with central necrosis (Table 1). Extrathoracic involvement (liver [$n = 2$], spleen [$n = 3$], and kidney [$n = 1$]) of tuberculosis was revealed in the chest CT scan in three patients with disseminated pulmonary nodules (Fig. 3D).

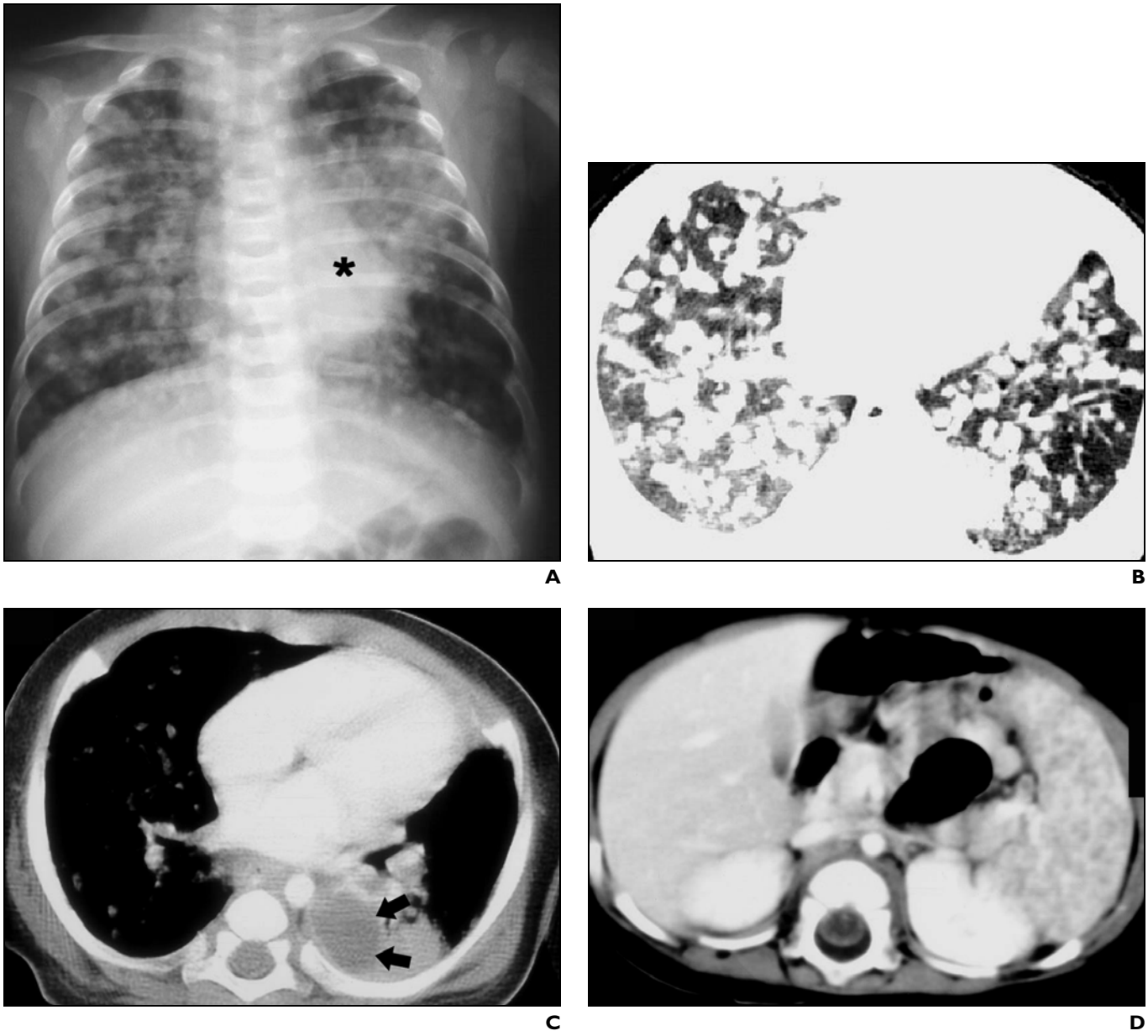
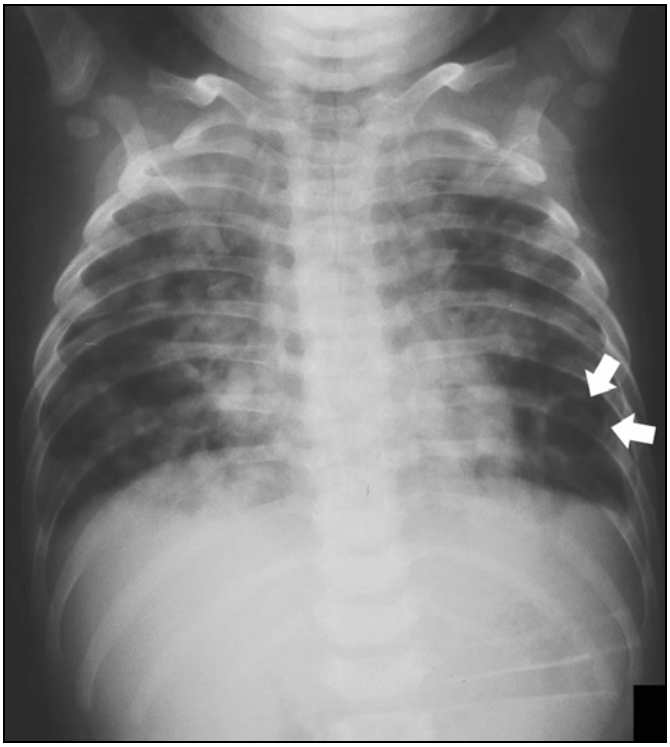


Fig. 3—4-month-old girl with systemic disseminated tuberculosis (patient 12).
A, Chest radiograph shows multiple disseminated nodules in both lungs and consolidation in left lower lung zone (*asterisk*).
B, Chest CT scan shows disseminated nodules of variable size. Most nodules are larger than 2 mm in diameter.
C, Enhanced CT scan shows consolidation with low-attenuation area (*arrows*) within it in superior segment of left lower lobe.
D, Numerous low-attenuation nodules are noted in spleen on enhanced CT scan.

Fig. 4—4-month-old boy with acute disseminated tuberculosis (patient 14). Cavitary changes in nodules are seen.
A, Chest radiograph shows numerous nodules in both lungs. Thin-walled cavity (*arrows*) is seen in left lower lobe.
B, On chest CT, multiple variable-sized nodules are detected. Cavity formation in some nodules is noted (*arrows*).
C, Follow-up chest radiograph obtained 1 year after **A** and **B** shows no parenchymal nodule in either lung.



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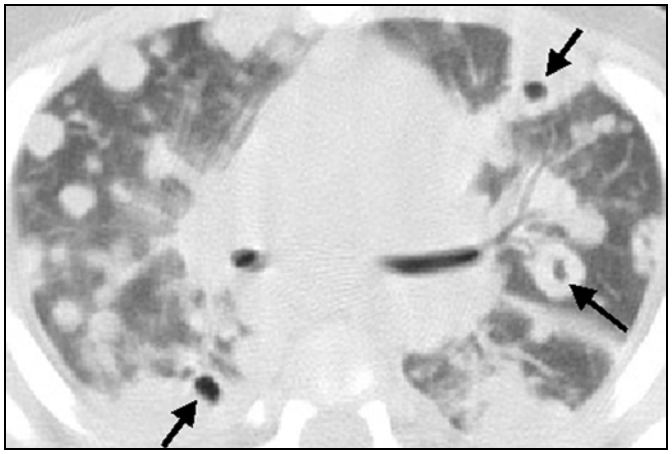

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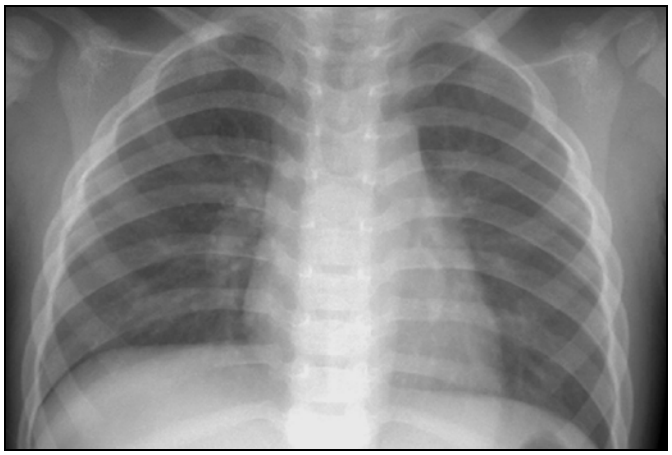

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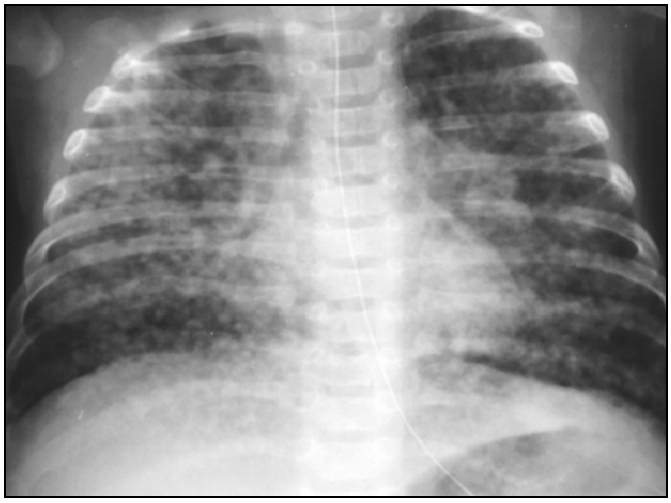
Follow-Up Chest Radiography

On follow-up chest radiographs (n = 23), mediastinal lymphadenopathy and parenchymal lesions had decreased in size in 74% (17/23) at 1 month after starting the patient's medication (Table 1). Improvement of the air-space consolidation preceded regression of enlarged nodes, and complete resolution of the consolidation occurred within 6 months (Fig. 4C) in all but the one patient who developed bullous parenchymal lesions and died due to respiratory failure. In two patients, residual lymphadenopathy was identified beyond 1 year (Table 2). New calcifications and decreased lung volume with focal fibrosis were noted in four patients and in three patients, respectively, among 18 patients, at 6 months (Fig. 5C). Bronchial narrowing, seen in four patients at initial radiography, was improved in all of these patients at follow-up radiography. The resolution of each radiographic finding after antituberculous medication is summarized in Table 2.

Discussion

Most pulmonary tuberculosis cases seen in infants are primary tuberculosis. The primary infection begins with deposition of infected droplets in the lung alveoli, followed by parenchymal inflammation [11, 21]. The initial inflammation produces localized alveolar consolidation, which is the primary focus. This may, although rarely, progress to involve a segment or an entire lobe and usually is not visible on chest radiographs [21, 22]. Infection then spreads to the central lymph nodes from the primary focus via draining lymphatic vessels (appearing as a linear interstitial pattern on chest radiographs) and results in regional lymphadenopathy. Together, the primary focus and the enlarged lymph nodes that drain it are called the Ranke complex [21–24]. In most cases, the mild parenchymal lesions and lymphadenopathy resolve spontaneously. In some cases, however, especially in young infants, the involved lymph nodes continue to enlarge [11]. Caseation necrosis of the regional lymph nodes progresses, and the enlarged nodes may compress the regional bronchi and cause bronchial narrowing, obstruction, and emphysema [21, 22]. As disease progresses, inflamed nodes can perforate neighboring bronchus and discharge caseous material into the bronchial tree, causing bronchogenic tuberculosis and focal or lobar pneumonia [25, 26].



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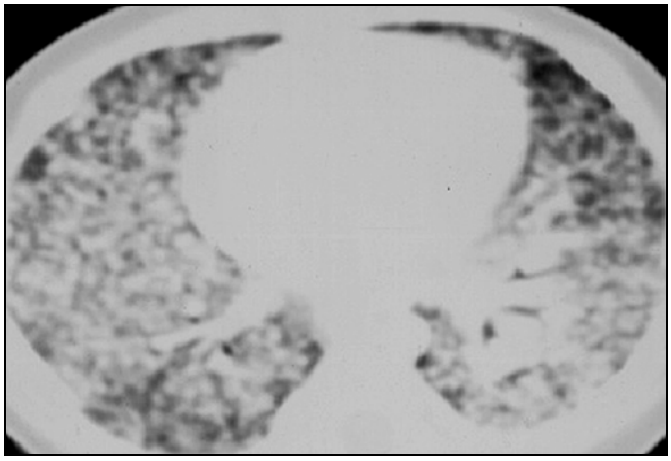

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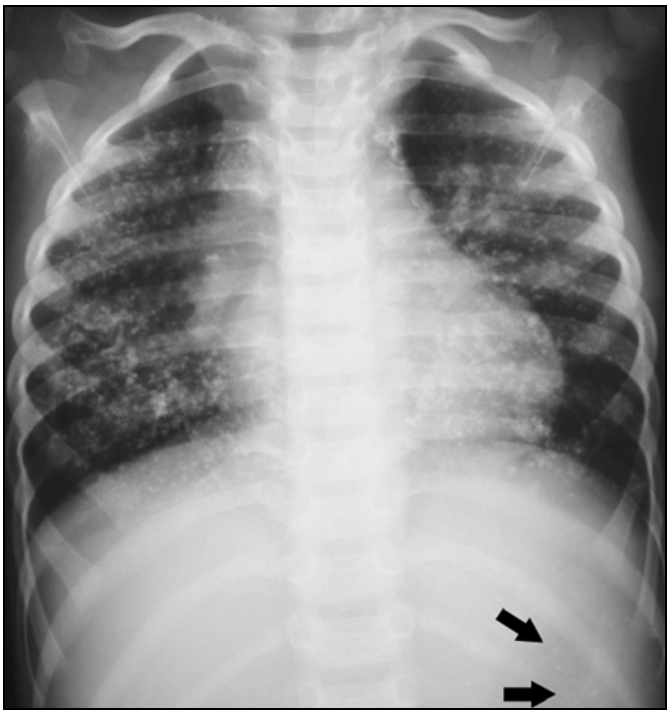

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Fig. 5—3-month-old boy (patient 1) with acute disseminated tuberculosis.
A, Chest radiograph shows multiple disseminated nodules with random distribution in both lungs.
B, Chest CT scan shows multiple small nodules in both lungs.
C, On follow-up chest radiograph obtained after antituberculosis medication for 1 year, nodules are healed, leaving multiple calcifications. Note multiple calcifications in spleen (*arrows*).

Mediastinal lymphadenopathy with or without parenchymal abnormality is a radiologic hallmark of primary tuberculosis in childhood [20–24]. In our study, chest radiography showed mediastinal lymphadenopathy and parenchymal abnormality in 72% and 96% of patients, respectively, and the most frequent radiographic finding of pulmonary parenchymal lesions was consolidation (80%). Leung et al. [20], in their series of 191 children, reported age-related differences in the prevalence of parenchymal abnormalities. Children 0–3 years old had a higher prevalence of lymphadenopathy (100%) and a lower prevalence of parenchymal abnormalities (51%) compared with those 4–15 years old. In their series, lymphadenopathy as the only radiologic manifestation of primary pulmonary tuberculosis was a feature of early childhood, occurring in 49% of cases; only 9% of patients in later childhood or adolescence showed such findings. However, in our study, most patients revealed parenchymal changes in conjunction with lymphadenopathy, and isolated mediastinal lymphadenopathy without parenchymal abnormality was rarely seen. In this study, chest radiography showed disseminated pulmonary tuberculosis in six patients (24%). All of them were 4 months of age or younger. Disseminated nodules were seen in the spleen ($n = 2$) or liver ($n = 1$) in CT scans of two patients with disseminated pulmonary tuberculosis (patients 3 and 12). Diffuse enlargement of the liver, spleen, and kidney was noted in one patient (patient 1) at CT scan. An MRI of the brain in one patient revealed tuberculous meningitis with disseminated tuberculomas (patient 3). In agreement with other studies [16, 17, 24], disseminated tuberculosis seemed to be more common in infants than older children.

It is well established that CT scans detect or confirm lymphadenopathy [12–15, 27]. Delacourt et al. [14], in their series of 15 children with tuberculous infection and negative chest radiography, found enlarged lymph nodes in 60% of patients on chest CT. On enhanced CT scans, tuberculous lymphadenopathy is seen as enlarged nodes with low-attenuation centers because of caseation necrosis and peripheral rim enhancement representing inflammatory hypervascularity [13, 27, 28]. In our study, CT scans delineated lymphadenopathy in four

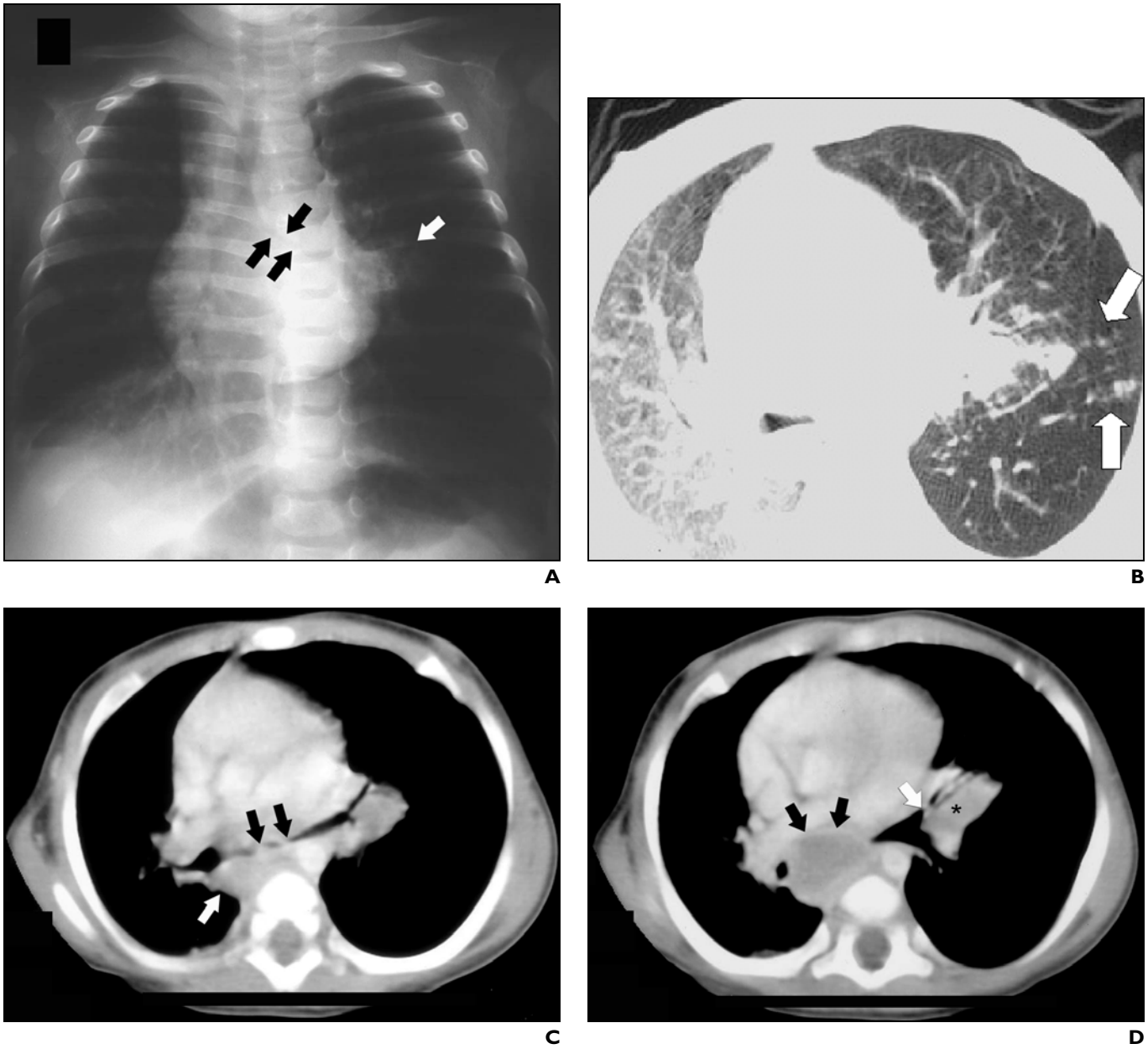

Fig. 6—5-month-old girl (patient 2) with bronchogenic spread of tuberculosis and bronchial stenosis.
A, Chest radiograph shows left hilar bulging (*white arrow*) and hyperinflation of left lung. Note narrowing of left main bronchus (*black arrows*).
B, High-resolution CT scan reveals peribronchial infiltrations and peripheral small nodules (*arrows*) suggesting bronchogenic spread of tuberculosis in left upper lobe. Hyperinflation of left lung is also noted.
C, CT scan shows narrowing of left main bronchus (*black arrows*) by enlarged subcarinal lymph nodes (*white arrow*).
D, Segmental bronchi (*white arrow*) of left upper lobe are also stenosed by hilar lymph nodes (*asterisk*). Note enlarged subcarinal lymph node with central low attenuation (*black arrows*).

patients who were not suspected to have lymphadenopathy on chest radiographs. Therefore, CT scans can be helpful in diagnosing tuberculosis when findings of chest radiographs are inconclusive.

In our study, air-space consolidation was the most common of parenchymal lesions seen on CT scans (100%), which was more common than that reported in the literature for childhood cases (19% [12] and 49% [13]). In this study, we frequently found masslike consolidation, which was well enhancing, volume preserving or expanding, and had no air bronchogram within it. As mentioned previously, enlarged hilar lymph nodes can compress neighboring regional bron-

TABLE 1: Radiographic and CT Findings of Pulmonary Tuberculosis in 25 Infants

Patients		Radiography							CT						
		Parenchymal Lesion			Mediastinal		Follow-up								
No.	Age (mo)/Sex	Cons	N	DN	Bulging	Others	1 mo	6 mo	Cons/Mass	Low/Cv	N-br	DN	LNE	Others	Extrathoracic
1	3/B	+		+	+		↓	Ca^{++}	+/–	–/+		+	+	Br	L, Sp, Kd
2	5/G	+			+	H, Br	↓	Ca^{++}	+/–		+		+	H, Pl	
3	2/G	+		+	+		N/A	N/A	+/–	+/–		+	+		L, Sp
4	5/B	+				H, A	NC	N/A	+/+		+		+ (*)	H, Br	
5	6/B	+	+		+	H	↓	↓V	+/–	+/+	+		+	H, Br	
6	3/B	+			+		↓	N/A	+/+				+ (Ca^{++})	H, Br	
7	7/B	+			+	H, Br	NC	Ca^{++}	+/+				+		
8	6/B	+			+	Br	NC	↓V	+/+		+		+		
9	4/B	+	+		+	H, Br, A	↓	NL	+/+		+		+	H	
10	6/B	+ (Cv)			+		↑	Deceased	+/–	+/+	+		+	Br, Pl, Pc, Be	
11	3/B	+	+			H	↓	NL	+/+	–/+	+		+ (*)	H, Br, Pl	
12	4/G	+		+	+	H	↓	NL	+/+	+/–		+	+	H, Br, Pc	Sp
13	5/G	+			+		↓	NL	+/+	+/–			+ (Ca^{++})	H, Br	
14	4/B	+ (Cv)		+ (Cv)			↓	NL	+/–	+/+		+ (Cv)	+ (*)	Br, Pl	
15	4/G	+			+		↓	↓V	+/+	+/–			+	Br, Pl	
16	4/G			+			↓	NL	+/–			+	+ (*)		
17	12/G	+			+		↓	Ca^{++}	+/+				+	Br	
18	12/B	+			+		↓	NL	N/A						
19	11/G	+	+		+		NC	N/A	N/A						
20	4/B	+			+	A	N/A	N/A	N/A						
21	8/G		+		+	A	↓	NL	N/A						
22	11/B	+	+				↓	NL	N/A						
23	3/G			+			NC	NL	N/A						
24	10/B		+				↓	N/A	N/A						
25	5/B				+		↓	NL	N/A						

Note—Cons = consolidation of air space, N = nodules, DN = disseminated nodules, Mass = masslike consolidation, Low = low attenuation within the consolidation, Cv = cavity, N-br = bronchogenically spread nodules, LNE = lymph node enlargement with central low attenuation and peripheral enhancement, Extrathoracic = extrathoracic involvement detected on chest CT scans, B = boy, ↓ = improved pulmonary lesions, Ca^{++} = calcification, Br = bronchial narrowing, L = liver involvement, Sp = spleen involvement, Kd = kidney involvement, G = girl, H = hyperinflation of the lung, Pl = pleural effusion or thickening, N/A = not available, A = atelectasis, NC = no change, ↓V = decreased lung volume with focal fibrosis, NL = normal, ↑ = aggravated pulmonary lesions, Pc = pericardial effusion or thickening, Be = bronchiectasis, (*) = lymph node detected only at CT.

chus and cause diffuse inflammation of the bronchus [21–23]. The common sequence is hilar lymphadenopathy, followed by atelectasis and consolidation [11]. The resulting radiographic findings have been called "collapse-consolidation," "segmental lesions," and "epituberculosis" [11, 22]. We believe the same disease process described as collapse-consolidation can explain masslike consolidation on CT scans in our study. Collapse-consolidation is more common in infants than older children and tends to occur within months of the initial infection [11]. Although masslike consolidation was found in 59% of the patients with consolidation on CT scans in our series, it was found in only 15% of patients in the study by Kim et al. [13] of childhood tuberculosis.

Low-attenuation areas within the consolidation, representing caseating necrosis, were also more common in our study, at 41%, than in that of Kim et al. [13], at 25%. Cavitations within consolidations were found in 29% of patients in our series. Cavitation, indicating high infectivity and high bacillary burden, is the hallmark radiographic findings in postprimary tuberculosis [21, 29], and it is rare in children with primary tuberculosis [11, 19–21]. Cavitation was frequently associated with low-attenuation areas within consolidations (3/5, 60%) in our study. Bullous or cystic lesions in the lung can develop as a rare complication. Necrosis and liquefaction in areas of pneumonic consolidation are thought to be the cause of extensive bullous lesions [30, 31]. In our study, one patient developed an extensive bullous lesion.

It is well established that CT scans have advantages over chest radiographs for detecting the brochogenic spread of tuberculosis [32] and miliary tuberculosis [16–18]. Although bronchogenic nodules were seen in only 29% of patients with childhood tuberculosis [13], they were found in 41% of patients in our study. Jamieson and Cremin [17] reviewed high-resolution CT findings of pulmonary tuberculosis in six young children with multiple disseminated nodules on chest radiographs. In their study, disseminated nodules varied in size and were even or irregular in distribution. They suggested using the term "acute disseminated tuberculosis" rather than "miliary tuberculo-

TABLE 2: Resolution of Radiographic Findings After Antituberculous Medication in Patients with Infantile Tuberculosis

Radiographic Findings	Follow-Up Times				
	Initial (*n* = 25)	1 month (*n* = 23)	3 months (*n* = 23)	6 months (*n* = 18)	1 year (*n* = 9)
Consolidation	20	13	7	0	0
Disseminated nodules	6	4	3	1	0
Mediastinal bulging	18	16	14	5	2
Newly appeared calcification	–	–	–	4	3
Fibrosis and decreased lung volume	–	–	–	3	3

Note—Data are numbers of patients.

sis" for pediatric patients because miliary nodules are defined as tiny nodules less than 2 mm in diameter, uniform in size, and widespread in distribution [33]. On CT scans in our study, disseminated nodules were seen in 29% of the patients. Nodules were larger (> 2 mm) than usual miliary nodules and coalesced with each other in three of five patients.

Infant airways are smaller and more easily compressed by enlarged hilar lymph nodes [8, 11, 34]. In our study, bronchial narrowing was seen in 65% and hyperinflation of lung parenchyma was seen in 47% of patients on CT scans. These airway complications were more common than those of childhood tuberculosis (bronchial narrowing in 37% [13] and 29% [27]). CT scans detect airway complications better than chest radiographs [34]. In seven of 11 patients with bronchial narrowing, we observed bronchial narrowing distal to the lobar bronchus on CT scans that was not seen on the chest radiographs.

Pleural effusion in primary tuberculosis results from pleural infection via direct extension—rupture of a subpleural lesion into the pleural space or spread from caseous lymphadenopathy or an adjacent spinal lesion [35]. Pleural effusion is not a common feature of primary pulmonary tuberculosis in young children, and it is rare in infants [8, 20]. In pleural tuberculosis, CT scans are also helpful for determining whether the thickening seen on chest radiographs represents pleural thickening; chronic loculated effusion, which usually needs decortication; or empyema [35]. Table 3 summarizes the previously reported radiographic and CT findings of infant and childhood primary pulmonary tuberculosis compared with our results.

Early diagnosis and prompt treatment, considering their duration of symptoms (< 1 week), was possible in only four patients in our study: three patients who showed definite mediastinal bulging on initial chest radiographs and had a positive Mantoux test, and one patient who showed miliary dissemination of tuberculosis at chest radiography and had a history of recent contact with active tuberculosis.

Radiographic regression of primary pulmonary tuberculosis is a slow process. In our study, complete resolution of the consolidation occurred after a maximum of 6 months of treatment, and improvement of the air-space consolidation preceded regression of enlarged nodes. Follow-up radiography after antituberculous medication may be performed to be sure that no progression or complications have occurred. It is not always necessary to achieve normal chest radiography to discontinue treatment [20, 36].

TABLE 3: Comparison of Radiographic and CT Features of Pulmonary Tuberculosis in Infancy and Childhood: Literature Review

Radiologic Studies	Our Study (*n* = 25)	Schaaf et al. [8] (*n* = 29)	Andronikou et al. [27] (*n* = 100)	Delacourt et al. [14] (*n* = 15)	Leung et al. [20] (*n* = 191)	Bosch-Marcet et al. [15] (*n* = 32)	Kim et al. [13] (*n* = 41)	Uzum et al. [12] (*n* = 48)
Mean age	5.9 mo	65 d	21.5 mo	2 y	5.9 y	6 y	6 y	7.9 y
Radiography								
Mediastinal LN	72	89		0	92	63		
Consolidation	80	71		0	70			
Disseminated nodules	24	26		0				
Airway compression	16	41		0				
CT								
Mediastinal LN	100		92	60		84[a]	83	73
Ring enhancement	100		67				85	
Consolidation	100						49	19[b]
Masslike consolidation	59						15	
Low attenuation	41						25	
Cavities	29							
Bronchogenic nodules	41						29	
Disseminated nodules	29						17	
Bronchial narrowing	65		29				37	

Note—Numbers in rows under Radiography and CT are all percentages. Cells left blank indicate incidence for this item was not mentioned in the study. LN = lymph node.
[a]Mediastinal lymph node detected on sonography.
[b]Parenchymal lesion including consolidation and atelectasis.

In summary, frequent radiologic findings of pulmonary tuberculosis of infants are mediastinal or hilar lymphadenopathy with central necrosis and air-space consolidations, especially masslike consolidations with low-attenuation areas or cavities within consolidations. Disseminated pulmonary nodules and airway complications are also frequently detected in this age group. CT can be a useful diagnostic technique for infant tuberculosis, as it can show parenchymal lesions and tuberculous lymphadenopathy better than chest radiography. CT scans can also be helpful when chest radiographs are inconclusive or complications of tuberculosis are suspected.

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