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CT findings in immunocompromised patients with pulmonary infections

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PURPOSE
To evaluate computed tomography (CT) findings of pulmonary infections in immunocompromised patients with hematologic malignancies, and to detect the accuracy of first-choice diagnoses.

MATERIALS AND METHODS
CT chest scans of 57 immunocompromised patients who had pulmonary infections were evaluated retrospectively, and a first and second interpretation of etiology (first- and second-choice diagnosis) was proposed. The etiology of pulmonary infection was verified by microbiological tests such as blood, sputum, bronchoalveolar lavage (BAL) cultures, sputum, and BAL smears, or diagnosed on the basis of response to treatment and clinical follow-up.

RESULTS
Nineteen patients had a bacterial infection, 20 patients had a fungal infection, 8 patients had a cytomegalovirus (CMV) infection, 8 patients had *Pneumocystis jiroveci* pneumonia (PCP) and 2 patients had a *Mycobacterium tuberculosis* infection. There were consolidations in 13 patients (68.4%) and areas of ground-glass attenuation and ground-glass nodules in 6 patients (31.6%) with bacterial infection. Six of 8 eight patients (75%) with CMV infection had centrilobular nodules associated with bronchial wall thickening and ground-glass areas and nodules. There were parenchymal nodules in 18 of 20 patients (90%) who had a fungal infection. All 8 patients who had PCP had bilateral areas of ground-glass densities on CT scans.

The first-choice diagnosis was accurate in most of the fungal infections (95.0%) and PCP (87.5%), but was less accurate for bacterial and viral infections (73.7% and 75.0%, respectively). Neither of the 2 tuberculous infections was identified on the basis of CT findings.

CONCLUSION
In the evaluation of febrile immunocompromised patients, pulmonary fungal infection and PCP may be identified with high accuracy on the basis of CT findings.

Key words: • *pneumonia* • *immunocompromised patient* • *tomography, X-ray computed*

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Pulmonary infections are an important cause of morbidity and mortality during the course of treatment of hematologic malignancies. Some of these infections are observed in the neutropenia period during myeloablative treatments, while others complicate bone marrow transplantations for approximately 1 year, until complete recovery of cellular and humoral immunity. During that time, bacterial, viral, fungal, and mycobacterial organisms may infect the lungs of immunosuppressed patients. Although infectious agents might be recovered in three-fourths of those patients, it may take time and require some invasive procedures, such as transbronchial biopsy and bronchoalveolar lavage. However, radiologic findings may be helpful in predicting the etiology of pulmonary infection and may ensure prompt treatment (1). The aim of our study was to evaluate computed tomography (CT) findings of pulmonary infections in febrile immunocompromised patients with hematologic malignancies, and to detect the accuracy of our first-choice diagnosis.

Materials and methods

Study patients

In the 4-year period between October 2000 and November 2004, 25 patients (11 females, 14 males) who underwent bone marrow transplantation at our hospital had pulmonary infiltrations visible on chest CT scans.

The diseases for which bone marrow transplantation was performed were Hodgkin disease (n = 3), non-Hodgkin lymphoma (n = 7), multiple myeloma (n = 7), acute myelogenous leukemia (n = 5), acute lymphoblastic leukemia (n = 1), aplastic anemia (n = 1), and myelodysplastic syndrome (n = 1). Seven of the 25 patients had received allogenic stem cell transplantation, whereas 18 had received autologous stem cell transplantation.

Within 30 days after transplantation (the early post-transplant period), 8 of the bone marrow transplantation patients developed pulmonary infections, and 5 patients developed infections within 31 to 100 days after transplantation; 12 patients developed pulmonary infections in the late post-transplant period (101 days and beyond). Only the 8 patients who developed infections in the early post-transplant period were neutropenic.

Other than bone marrow transplantation patients, 32 patients (20 males, 12 females) in our clinic developed neutropenic fever during their treatment, and had pulmonary infiltrations on chest CT scans; these patients were included in the study. Their diseases were Hodgkin disease (n = 3), non-Hodgkin lymphoma (n = 6), acute myelogenous leukemia (n = 10), chronic myelocytic leukemia (n = 1), myelodysplastic syndrome (n = 1), acute lymphoblastic leukemia (n = 7), chronic

lymphocytic leukemia (n = 3), and adenocarcinoma of stomach (n = 1).

The patients in our entire study group were between 17 and 75 years old with a mean age 45.6 years.

The etiology of pulmonary infection was detected by microbiological tests such as blood, sputum, and bronchoalveolar lavage (BAL) cultures, and sputum and BAL smears.

Bacterial infection was diagnosed on the basis of positive blood culture results or detection of bacteria on BAL smears in 9 patients. *Staphylococcus aureus* was isolated in blood cultures of 5 patients, and *Streptococcus pneumonia, Pseudomonas aeruginosa* and *Enterococcus* were isolated in 1 patient each. In 1 patient, *S. aureus* was isolated from a BAL culture; in 10 patients, the diagnosis of bacterial infection was based on response to empirical antimicrobiological treatment and clinical follow-up. Fungal infection was diagnosed in 7 patients on the basis of response to treatment in clinical follow-up. In 10 patients, *Aspergillus* infection was diagnosed by a positive galactomannan-antigen test. In 3 patients, *Candida albicans* was isolated in blood cultures. *Cytomegalovirus* (CMV) antigenemia was detected in 8 patients. The diagnosis of *Pneumocystis jiroveci* pneumonia (PCP) infection depended on identification of the cystic form of the organism in BAL fluid samples of 8 patients. *Mycobacterium tuberculosis* infection was diagnosed in 2 patients from the results of a polymerase chain reaction test.

The 47 patients in our study group had chest CT scans performed at our institution with a 4-slice CT scanner (Volume Zoom, Siemens Medical Solutions, Erlangen, Germany). In 45 patients, CT was performed according to a standard single-breath–hold protocol (80 effective mAs, 120 kV). Section thickness was 5 mm, with a pitch of 3 at 0.5 s per gantry rotation. In the other 2 patients, high resolution CT of the lung was obtained with 1 mm slice thickness in every 10 mm with 100 mA, 120 kV and 0.75 s scan time. In 10 patients, the CT was performed at another hospital center with 10 mm collimation. Neutropenic patients were evaluated by a chest CT if they did not respond to empirical antibacterial treatment within 5 days.

Radiologic evaluation

The chest CT scans were evaluated retrospectively by a radiologist with 15 years' experience in chest radiology. If the patient had more than one chest CT scan, the CT done closest in time to the beginning of febrile episode and diagnostic microbiological tests was assessed. Most of the parenchymal findings were defined according to the recommendations of Webb et al. (2).

Homogeneous amorphous opacification, which often obscures the underlying vessels with air bronchograms, was defined as consolidation. A ground-glass area is a patchy or diffuse, hazy increase in lung opacity that does not obscure the underlying vessels. Ground-glass nodules are small, round, focal ground-glass opacities. Centrilobular nodules represent opacities centered within the lobule surrounding centrilobular arteries, and may range from a few millimeters to a centimeter in size. An acinar nodule is a small, ill-defined nodular opacity, usually ranging from a few millimeters to 1 centimeter in diameter that can be observed in patients with airspace diseases. Interlobular septal thickening represents an abnormal thickening of interlobular septa, usually a result of fibrosis, edema, or infiltration by cells or other material. Nodules are focal, rounded opacities of varying size, either well- or ill-defined. In this study, rounded opacities without any specific features were simply defined as a "nodule"; a "cavitary nodule" is a nodule containing air.

After the evaluation of the parenchymal findings, a first- and second-choice diagnosis was made without knowledge of laboratory findings and before follow-up of patients. Either bacterial (PCP or *Mycobacterium tuberculosis*), fungal, viral etiology was suggested as the first- or second-choice diagnosis. Bacterial infection was considered as the first-choice diagnosis in patients with consolidations, whereas viral infection was suggested by the presence of centrilobular nodules, ground-glass nodules and densities, thickening of bronchial walls, and interlobular septa. Our first-choice diagnosis was PCP in patients with bilateral ground-glass areas on the chest CT. Fungal infection was suggested as the first-choice diagnosis in patients with nodules on the chest CT that did not have any specific features, such as centrilobular nodules or acinary nodules. Cavitary nodules were assumed to be a sign of fungal infection.

Results

In our study group of 57 immunocompromised patients, 19 patients had bacterial infections, 20 patients had fungal infections, 8 patients had CMV infections, 8 patients had PCP infections, and 2 patients had *Mycobacterium tuberculosis* infection. Fungal infection was the most common infection type in patients with febrile neutropenia; it was detected in 14 of 32 (44%) neutropenic patients. In patients who had undergone bone marrow transplantation, bacterial infection was the most common type of infection (11 of 25 patients; 44%). First- and second-diagnostic choices of pulmonary infection etiology in these patients on the basis of CT findings are shown in Table 1.

Table 1. First- and second-choice diagnoses of pulmonary infection etiology in hematologic malignancies on the basis of chest CT findings among 57 immunocompromised patients

	First-choice diagnoses				Second-choice diagnoses			
INFECTION TYPE	B	V	F	PCP	B	V	F	PCP
Bacterial (n = 19)	14	3	2	-	5	14	-	-
Viral (n = 8)	2	6	-	-	6	2	-	-
Fungal (n = 20)	1	-	19	-	15	4	1	-
PCP (n = 8)	1	-	-	7	2	6	-	-
Tuberculous (n = 2)	-	1	1	-	2	-	-	-

B, bacterial; V, viral; F, fungal; PCP, pneumocystis jiroveci pneumonia.

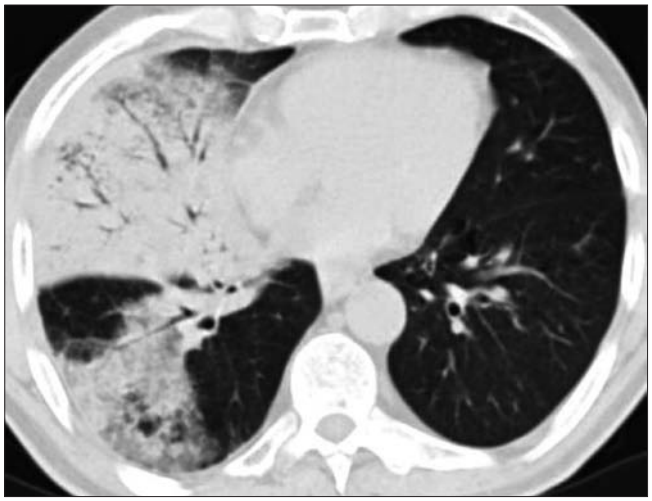

Figure 1. Axial CT image shows consolidation with air bronchograms in a 69-year-old patient with chronic lymphocytic leukemia and neutropenia. Blood culture showed *Streptococcus pneumonia.*

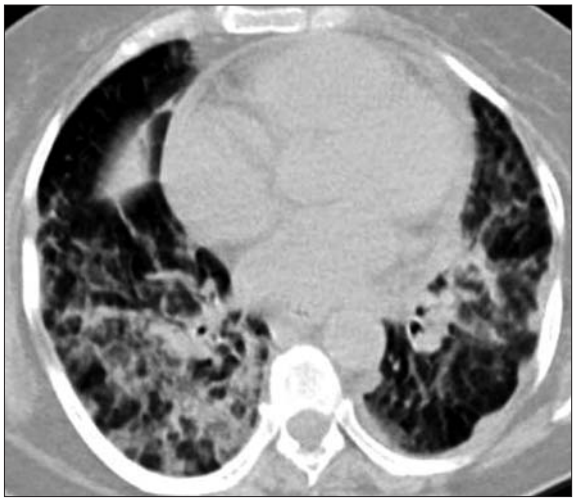

Figure 2. Axial CT image shows bilateral consolidation and ground-glass densities in a 61-year-old bone marrow recipient with myelodysplastic syndrome. *Staphylococcus aureus* was cultured from bronchoalveolar lavage.

Bacterial infections

In 13 of 19 patients (68.4%) with bacterial infection, there were consolidations on chest CT scans (Table 2) (Fig. 1). Ground-glass areas, ground-glass nodules, centrilobular nodules, and thickening of bronchial walls were detected in association with consolidation (Fig. 2). In 6 patients without consolidation (31.6%), ground-glass areas and nodules (centrilobular or acinar nodules) were signs of lung infection. Pleural effusion was detected in 4 patients; 3 with consolidation and 1 with centrilobular nodules. Thickening of bronchial walls was detected in 6 patients in association with consolidation, ground-glass areas, and centrilobular nodules.

The first-choice diagnosis of etiology was correct in 14 out of 19 patients (73.7%) with bacterial infection. Viral infection was the second-choice diagnosis in these patients. The chest CT suggested fungal infection in 2 patients and viral infection in 3 patients as the first-choice diagnosis. Bacterial etiology had been selected as the first- or second-choice diagnosis on the basis of CT findings in all patients with a bacterial infection.

Viral infections

CMV infection was detected in 8 patients (Table 2). In 6 of them (75%), centrilobular nodules were detected on chest CT scans, whereas consolidation was seen in the other 2 patients (Fig. 3). The centrilobular nodules were associated with bronchial wall thickening in 4 patients and with ground-glass nodules or densities in 5 patients (Fig. 4). In the patients with consolidation, ground-glass nodules were observed in one patient, and bronchial wall thickening was observed in the other patient.

Viral etiology was accurate as the first-choice diagnosis on the basis of CT findings in 6 of 8 patients (75%). Bacterial etiology was the second-choice diagnosis in these patients. In 2 patients for whom bacterial etiology was the first-choice diagnosis, viral etiology was the second-choice diagnosis.

Fungal infections

Fungal infection was detected in 20 patients (Table 3). In 10 patients, *Aspergillus* infection was determined on the basis of the positivity of galactomannan antigen. Ill-defined nodules were detected in 9 patients with Aspergillus infection (Table 3). In 4 of 9 patients, some of the nodules were cavitary (Fig. 5). Nodules with or without a cavity were associated with consolidation in 3 patients, centrilobular nodules in 2 patients, ground-glass nodules in another 2 patients, and bronchial wall thickening in 1 patient. The only

Table 2. Chest CT findings in immunocompromised patients with pulmonary bacterial infection and pulmonary cytomegalovirus (CMV) infection

	Bacterial infection (n = 19)		CMV infection (n = 8)	
CT findings	n	%	n	%
Consolidation	13	68.4	2	25.0
Ground-glass area	6	31.6	3	37.5
Ground-glass nodules	6	31.6	3	37.5
Nodule	1	5.3	0	0.0
Cavitary nodule	0	0.0	0	0.0
Centrilobular nodules	6	31.6	6	75.0
Acinar nodules	2	10.5	0	0.0
Interlobular septal thickening	1	5.3	0	0.0
Thickening of bronchial wall	6	31.6	5	62.5
Pleural effusion	4	21.1	0	0.0

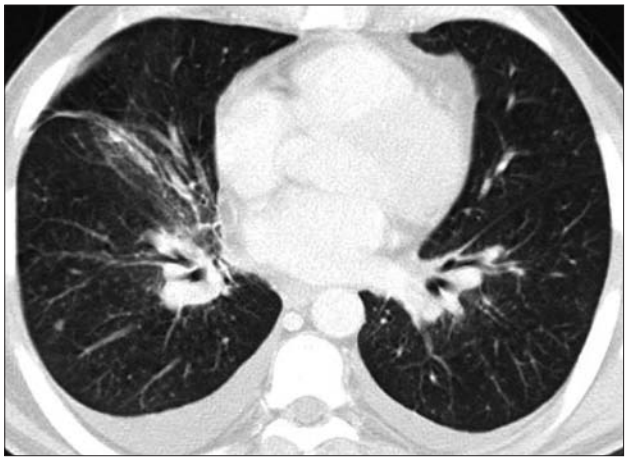

Figure 3. Axial CT image shows bilateral centrilobular nodules and pleural effusion in *Cytomegalovirus* infection in a 38-year-old bone marrow recipient.

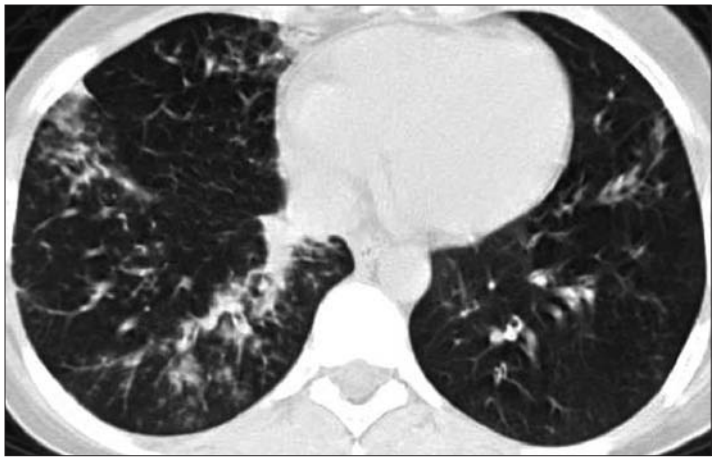

Figure 4. Axial CT image shows bilateral centrilobular nodules, ground-glass densities and thickening of bronchial walls predominantly in the right lower lobe in a bone marrow recipient with *Cytomegalovirus* antigenemia.

patient without a nodule had areas of ground-glass density and thickening of the bronchial wall.

Candida albicans infection was detected by blood culture in 3 patients; in all 3, CT scans showed nodules without a cavity (Fig. 6). These nodules were smaller than 10 mm in all 3 patients, with consolidation in one of them. In one of the three patients, the nodules were associated with ground-glass nodules.

The etiology of pulmonary infection was not proven on the basis of the original chest CT in 7 patients, but those patients responded to antifungal therapy according to both clinical and CT findings. In 6 of 7 patients, there were nodules on the CT scans, and 4 patients had at least 1 cavitary nodule.

When all patients with fungal infection were considered, there were nodules in 90%; 40% of the patients had cavitary nodules. An air-crescent sign was present in 4 of the 8 patients with cavitary nodules (Fig. 5).

In 19 of 20 patients, fungal infection was the first-choice diagnosis (95%); in 4 patients, viral etiology; and in 15 patients, bacterial etiology was the second–choice diagnosis. Bacterial infection was the first-choice diagnosis in only 1 patient with fungal infection; however, in that patient, fungal etiology was the second-choice diagnosis.

Pneumocystis jiroveci pneumonia

In all 8 patients with PCP, there were areas of ground-glass density on CT scans (Table 3). In 7 patients, the ground-glass densities were bilateral and diffuse, whereas in the eighth patient, they were localized and central (Fig. 7). Ground-glass densities were associated with consolidation in 2 patients, bronchial wall thickening in 3 patients, and interlobular septal thickening in 2 patients. In 1 patient, both

Table 3. Chest CT findings in immunocompromised patients with pulmonary fungal infection, aspergillus infection, and *Pneumocystis jiroveci* pneumonia (PCP)

	Fungal infection (n = 20)		Aspergillus infection (n = 10)		PCP (n = 8)	
CT findings	n	%	n	%	n	%
Consolidation	7	35	3	30.0	2	25.0
Ground-glass area	0	0.0	0	0.0	8	100.0
Ground-glass nodules	6	30.0	3	30.0	5	62.5
Nodule	18	90.0	9	90.0	0	0.0
Cavitary nodule	8	40.0	4	40.0	0	0.0
Centrilobular nodules	4	20.0	2	20.0	0	0.0
Acinar nodules	1	5.0	0	0.0	1	12.5
Interlobular septal thickening	0	0.0	0	0.0	2	25.0
Thickening of bronchial wall	4	20.0	2	20.0	3	37.5
Pleural effusion	4	20.0	1	10.0	0	0.0

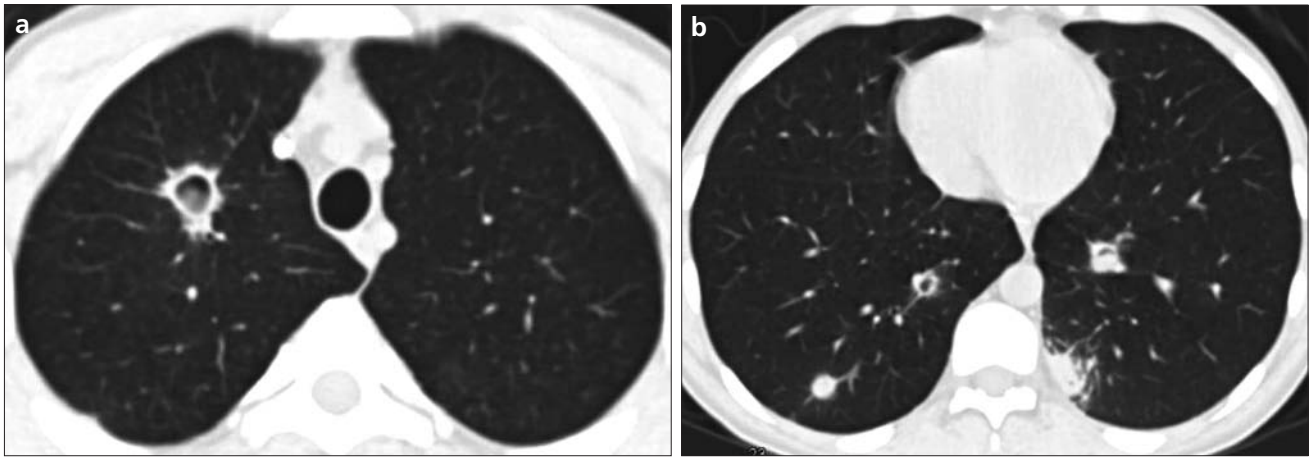

Figure 5. a, b. Axial CT images **(a, b)** showing bilateral cavitary nodules with air crescent sign in a 33-year-old neutropenic patient with acute lymphoblastic leukemia. Invasive aspergillosis was diagnosed on the basis of galactomannan positivity.

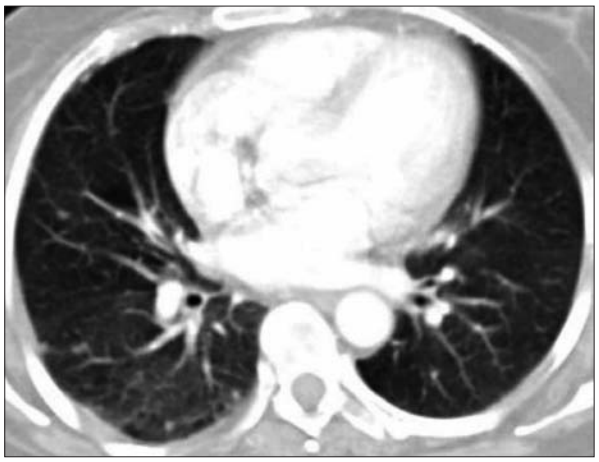

Figure 6. Axial CT image shows small nodules in the right middle and lower lobes in a neutropenic patient with acute lymphoblastic leukemia. Her blood culture revealed *Candida albicans*.

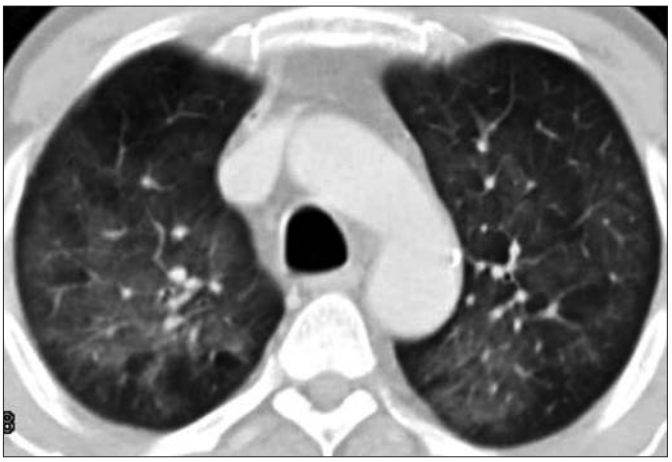

Figure 7. Axial CT image shows bilateral ground glass density in the upper lobes of a 51-year-old female neutropenic patient with *Pneumocystis jiroveci* pneumonia.

interlobular septal thickening and bronchial wall thickening were detected with ground-glass densities.

Pneumocystis jiroveci was the first-choice diagnosis of etiology in 7 out of 8 patients with PCP (87.5%). Viral etiology was the second-choice diagnosis in 5 patients, and bacterial etiology was the second-choice diagnosis in 2 patients. In only 1 patient with PCP, bacterial etiology was the first-choice diagnosis, whereas viral etiology was the second-choice diagnosis.

Mycobacterium tuberculosis infection

In 2 of the 57 immunocompromised patients, *M. tuberculosis* infection was detected. One patient had consolidation with centrilobular nodules, acinar nodules, and interstitial thickening, whereas the other patient had consolidation with nodules (Fig. 8).

Discussion

The lung is the most frequently affected organ in immunocompromised patients, and infections are the most commonly encountered pulmonary complications in these patients. Because of the high risk of mortality and morbidity, pulmonary infections need prompt diagnosis and treatment. However, bacteriological evaluation may take time and cause a delay in diagnosis. Although some empirical treatment regimens have been developed and used in such cases, radiological findings may be helpful in expediting differential diagnosis of infections and in the selection of appropriate antibiotics.

Chest radiography has an important role in detection of pulmonary infiltrations and in following up the response to treatment. However, chest radiography has lower sensitivity for detection of early infections, and findings are often non-specific (3). In addition, because of the depressed inflammatory reaction, chest radiography findings may be difficult to observe and evaluate. CT may overcome some limitations of chest radiography; for instance, CT can detect 20% more pneumonias in patients with pulmonary infections 5 days earlier than chest X-ray (4). Therefore, CT is indicated in patients with febrile neutropenia, and normal or questionable chest radiography findings. In addition, chest CT may provide greater confidence in differential diagnosis of infectious and noninfectious pulmonary complications, especially if the optimal biopsy type and site are selected (5).

The radiological findings of bacterial infection are identical in immu-

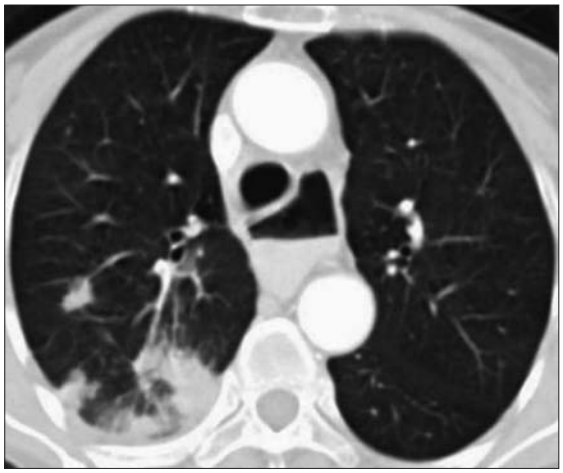

Figure 8. Axial CT image shows consolidation and ill-defined nodules in the posterior segment of right upper lobe in a neutropenic patient with tuberculous infection.

nocompetent and immunocompromised patients, and manifest most frequently as focal areas of consolidation (6). Consistent with the literature, we found consolidation in 13 of 19 patients (68.4%) with bacterial infection. In some patients, the consolidations were accompanied by ground-glass densities, ground-glass nodules, centrilobular nodules, thickening of bronchial walls, and pleural effusion. In 6 patients without consolidation, centrilobular nodules, acinar nodules, ground-glass densities, and ground-glass nodules were signs of infection. These findings are consistent with a bronchopneumonia that is associated with the presence of bronchial and peribronchiolar inflammatory exudates, which also involve surrounding alveoli (7). Although bronchopneumonia most commonly results from *Staphyloccocus* and gram-negative bacteria, various organisms such as viruses and *P. jiroveci* may cause bronchopneumonia. Therefore, in patients with bronchopneumonia findings, the etiology of infection can not be verified on the basis of radiological findings.

In CMV infection, CT may show patchy or diffuse consolidation, ground-glass opacities, small centrilobular nodules, bronchial wall thickening, a combination of consolidation and reticular opacities, and pleural effusion (8). Franquet et al. reported that ground-glass opacification was detected in 21 of 32 (66%) patients with CMV infection; CT findings also included multiple nodules and air space consolidation (9). In this study, the nodules were centrilobular in 10 patients (31.2%) and thickening of the bronchovascular bundle was observed in 7 patients (22%). Moon et al. reported ground-glass opacities in all 10 of their study patients and centrilobular nodules in 9 out of the 10 patients (10). Consistent with those studies, we detected centrilobular nodules (75%) and ground-glass density-nodules (37.5%) in patients with CMV infections. In contrast, however, we observed bronchovascular bundle thickening more frequently, in 62.5% of patients.

In the present study, we observed that ground-glass nodules and densities, centrilobular nodules, and thickening of bronchial walls may be found in both bacterial and viral infection. If these findings are not associated with consolidation, although the probability of viral infection is high, the possibility of bacterial infection cannot be excluded. That coincidence explains the low accuracy of our first-choice diagnosis on the basis of CT findings in bacterial and viral infections (73.7% and 75%, respectively). However, our findings of the coincidental occurrence of bacterial and viral infection, which are ground-glass densities and nodules, centrilobular nodules and thickening of bronchial walls, will serve to alert physicians to look for both etiologies when using CT as a diagnostic tool.

Invasive aspergillosis almost always occurs in an immunocompromised host, and causes significant hemorrhagic infarction and tissue necrosis. Early in the course of infection, CT may reveal single or multiple nodules, often with surrounding ground-glass opacity, the so-called "halo" sign. This sign represents hemorrhage and necrosis around the central necrotic nodule containing *Aspergillus* hyphae (11). However, the halo sign is neither sensitive nor specific for invasive aspergillosis; it is reported in 50% of cases. The halo sign may be detected in other infections, neoplasms (adenocarcinoma, bronchoalveolar carcinoma, Kaposi sarcoma, and metastases), Wegener granulomatosis, or other processes (12). Nevertheless, it is an early sign and may enable accurate and timely diagnosis in the appropriate clinical context. We did not evaluate the halo sign, because most of our CT scans were done with 5 to 10 mm collimation.

Heussel et al. reported that Aspergillus infection is often associated with ground-glass opacities, ill-defined nodules, and consolidation (13). Mori et al. reported that CT showed nodules in 20 of 21 febrile bone marrow recipients, and cavitary nodules in 7 of these 20 patients (14). Consistent with these reports, we detected nodules in 9 out of 10 patients with Aspergillus infection; 4 of those 9 patients had cavitary nodules. There were consolidation in 3 patients; however, these were associated with cavitary nodules in 2 patients and noncavitary nodules in 1 patient.

Although pulmonary candidiasis had been considered an uncommon complication in immunocompromised patients, it has been increasingly diagnosed as a type of fungal infection. However, CT findings of pulmonary candidiasis are not well known. We detected *Candida* infection of the lungs in 3 of 57 patients in our study. In all 3 patients, there were nodules without cavity. In addition, we detected consolidation in 2 of the 3 patients and ground-glass densities of nodules in all 3 patients. Consistent with our study, Janzen et al. have reported a predominantly nodular pattern with halo surrounding the nodules in 60% of non-AIDS patients (15).

In our study, 7 patients in whom infection etiology could not be differentiated by clinical testing responded to antifungal treatment. Because these patients had not responded to empirical antibacterial antibiotics started before antifungal treatment for 5 days, they were assumed to have fungal infection. Six out of those 7 patients had nodules, and 4 nodules were cavitary.

When all the fungal infections were considered, the most common find-

ing was nodules (90%). Some of them were cavitary (40%), and in half of the patients with cavitary nodules, we observed the air crescent sign, a nodular opacity that represents retracted and infarcted lung associated with crescentic or circumferential cavitation. Although this sign is not specific for invasive aspergillosis, it is highly characteristic when observed under appropriate clinical conditions (16). In this study, our first-choice diagnosis was highly accurate (95%) in predicting fungal infection. Won et al. reported a lower ratio (50%) in diagnosis of aspergillus infection (17). In our opinion, immunocompromised febrile patients with ill-defined nodules on the CT scan that do not respond to treatment for bacterial and viral infections should be investigated for fungal infection.

Pneumocystis jiroveci is a unicellular organism that was originally classified as a protozoan because it responded to antiprotozoan medications such as pentamidine. However, recent studies suggest that *P. jiroveci* may be a fungus (18). In the exudative phase of infection the alveoli fill with a foamy eosinophilic exudate that contains both trophozite and cystic forms of the organism, as well as fibrin and dead pneumocytes. The exudative phase of PCP is manifested by hazy, granular opacities on chest radiographs and as ground-glass attenuation on high-resolution CT (HRCT) examinations. In the interstitial phase of infection, type II pneumocytes proliferate to repair the gap in the alveolar basement membrane; macrophages and monocytes then migrate into the lung interstitium. The interstitial phase of infection is characterized by the presence of reticular opacities on chest X rays, and intra- and inter-lobular septal thickening on HRCT scans (18). Bergin et al. showed that the predominant CT finding was areas of ground-glass opacity, or consolidation, or both (19). A central or perihilar opacity may be present, and is considered typical of PCP.

Our findings are consistent with previous studies in that we detected areas of ground-glass opacities in all 8 patients with PCP; they were diffuse in 7 patients. In 2 cases, consolidation was detected in association with ground-glass densities. Thickening of bronchial walls and interlobular septal thickening were additional findings. Our findings indicate that the presence of diffuse ground-glass opacities not associated with centrilobular nodules and cavitary nodules are highly suggestive of *P. jiroveci* infection. In our study, the accuracy of first-choice diagnosis was 87.5% in PCP. This is consistent with the study of Kang et al., who reported 87% accuracy of a confident first-choice diagnosis of PCP in patients with AIDS (20).

In our study, 2 patients with febrile neutropenia had *Mycobacterium tuberculosis* infection. One patient with adenocarcinoma of stomach had consolidation in the posterior segment of the upper lobe with nodules in the both lungs. Gastrectomy might have been a risk factor for the reactivation of tuberculosis in that patient. The other patient with acute lymphocytic leukemia had ground-glass nodules associated with centrilobular nodules, interlobular septal thickening, and bronchial wall thickening. We had diagnosed tuberculous infection in neither of those 2 patients, perhaps because of the absence of the typical cavitary consolidation of tuberculosis. However, tuberculous infection should always be considered as a possible diagnosis for the febrile immunocompromised patients.

In the bone marrow transplantation population, infections occur as a result of immunosuppression induced by transplantation. The time elapsed since transplantation may be helpful in predicting the etiology of pulmonary infections. In the pre-engrafment period (0–30 days), bacterial and fungal infections are common as a result of neutropenia and damaged mucosal membranes. Between 31–100 days post-transplantation, both cellular and humoral immunity are impaired; CMV is the most likely invasive pathogen in this time period. Immunosuppressive agents administrated for graft-versus-host disease may lead to bacterial and fungal infections. In the late post-transplantation period (day 101 and beyond), infection is uncommon unless the patient has chronic graft-versus-host disease (1). In the present study, we evaluated the CT findings of pulmonary infections in immunocompromised patients, and aimed to detect our accuracy of the first-choice diagnosis of type of infection; the patients whose fever responded to empirical therapy and did not have chest CT scans were not included in this study. Therefore, we did not determine the frequency of pathogens according to transplantation periods and made our decisions without taking the period into consideration.

Our study has some limitations. First, because of the limitations of bronchoscopic and microbiological studies, diagnosis of some infections were based on response to empirical antimicrobiological treatment and clinical follow-up. Second, most of the CT scans were obtained by a four-detector CT scanner with 5 mm collimation. Although the scanner resolution provides sufficient information for differential diagnosis of pulmonary infections, some high-resolution CT features, such as the halo sign, could not be evaluated. In our hospital, because of our uncertainty in detection of small nodules located in the gaps between HRCT slices, we routinely obtain spiral CT for the evaluation of patients with neutropenic fever. Thin slices were reconstructed or HRCT was obtained thereafter if necessary.

In summary, pulmonary fungal infection can be predicted in febrile immunocompromised patients with high accuracy if the patient have nodules on CT. Diffuse ground-glass opacities are highly indicative of *P. jiroveci* infection. However, the bacterial or viral etiology cannot be differentiated with high accuracy.

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