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Thin-section CT findings of patients with acute *Streptococcus pneumoniae* pneumonia with and without concurrent infection

F OKADA, MD, Y ANDO, MD, S MATSUSHITA, MD, R ISHII, MD, T NAKAYAMA, MD, K MORIKAWA, RT, A ONO, MD, T MAEDA, MD and H MORI, MD

Department of Radiology, Oita University Faculty of Medicine, Oita, Japan

Objectives: The aim of this study was to compare the pulmonary thin-section CT findings of patients with acute *Streptococcus pneumoniae* pneumonia with and without concurrent infection.
Methods: The study group comprised 86 patients with acute *S. pneumoniae* pneumonia, 36 patients with *S. pneumoniae* pneumonia combined with *Haemophilus influenzae* infection, 26 patients with *S. pneumoniae* pneumonia combined with *Pseudomonas aeruginosa* infection and 22 patients with *S. pneumoniae* pneumonia combined with methicillin-susceptible *Staphylococcus aureus* (MSSA) infection. We compared the thin-section CT findings among the groups.
Results: Centrilobular nodules and bronchial wall thickening were significantly more frequent in patients with pneumonia caused by concurrent infection (*H. influenzae*: $p<0.001$ and $p<0.001$, *P. aeruginosa*: $p<0.001$ and $p<0.001$, MSSA: $p<0.001$ and $p<0.001$, respectively) than in those infected with *S. pneumoniae* alone. Cavity and bilateral pleural effusions were significantly more frequent in cases of *S. pneumoniae* pneumonia with concurrent *P. aeruginosa* infection than in cases of *S. pneumoniae* pneumonia alone ($p<0.001$ and $p<0.001$, respectively) or with concurrent *H. influenzae* ($p<0.05$ and $p<0.001$, respectively) or MSSA infection ($p<0.05$ and $p<0.05$, respectively).
Conclusions: When a patient with *S. pneumoniae* pneumonia has centrilobular nodules, bronchial wall thickening, cavity or bilateral pleural effusions on CT images, concurrent infection should be considered.

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Streptococcus pneumoniae has long been recognised as the most common cause of community-acquired pneumonia (CAP) and is responsible for the increasing frequency of nosocomial pneumonia [1–3]. The mortality associated with pneumonia is linked to inadequate initial antibiotic therapy; therefore, early detection of *S. pneumoniae* pneumonia is important for reducing morbidity and mortality.

A rapid immunochromatographic membrane test was developed for the detection of *S. pneumoniae* antigens in urine samples [4]. It is a useful technique for the rapid diagnosis of pneumococcal pneumonia; however, the urinary antigens cannot be detected a few days after *S. pneumoniae* infection, and this test is unable to detect concurrent pathogen infections.

Most cases of CAP are probably caused by a single pathogen, but dual or multiple infections have been increasingly reported in the literature [5–8]. There is growing concern for the concurrent presence of a second pathogen in a significant proportion of cases of CAP previously thought to be monomicrobial [5, 7–10]. De Roux et al [8] reported that in 82 patients with mixed CAP, *S. pneumoniae* was the most prevalent microorganism ($n=44$), that the most frequent combination of organisms was *S. pneumoniae* with *Haemophilus influenzae* ($n=17$) and that patients with mixed pyogenic pneumonia more frequently developed shock than patients with single pyogenic pneumonia.

The classic chest radiographic appearances of pneumococcal pneumonia have been described as sublobar, lobar or multilobar opacities, often homogeneous with an air bronchogram [11–13]. As for CT findings, a few studies have been reported in patients with *S. pneumoniae* pneumonia; Miyashita et al [14] reported CT findings in 68 patients with *S. pneumoniae* pneumonia who were not infected with any other microorganisms.

However, to the best of our knowledge, no studies have been published that compare CT findings in patients with *S. pneumoniae* pneumonia alone with those displaying concurrent pneumonia caused by *S. pneumoniae* and another pathogen. The present study therefore compared the pulmonary thin-section CT findings of patients with acute *S. pneumoniae* pneumonia alone with those of patients with concurrent *S. pneumoniae* pneumonia.

Methods and materials

Patients

Our institutional review board approved this retrospective study, and waived the requirement for informed consent. We retrospectively identified 363 patients with acute *S. pneumoniae* pneumonia (122 patients with *S. pneumoniae* pneumonia alone and 241 patients with concurrent *S. pneumoniae* pneumonia) between January

Address correspondence to: Dr Fumito Okada, Department of Radiology, Oita University Faculty of Medicine, 1-1 Idaigaoka, Hasama-machi, Yufu, Oita 879-5593, Japan. E-mail: fumitook@med.oita-u.ac.jp

2004 and July 2010 at our institution (Table 1). Among the concurrent pathogens, *H. influenzae* was the most frequent (n=85), followed by *Pseudomonas aeruginosa* (n=48) and methicillin-susceptible *Staphylococcus aureus* (MSSA; n=37). 86 of the 122 patients with *S. pneumoniae* pneumonia alone and 129 of the 241 patients with concurrent *S. pneumoniae* pneumonia underwent chest thin-section CT examinations. The study group comprised 86 patients (45 male, 41 female; age range 23–98 years, mean age 61.3 years) with acute *S. pneumoniae* pneumonia, 36 patients (27 male, 9 female; age range 31–94 years, mean age 67.2 years) with *S. pneumoniae* pneumonia combined with *H. influenzae*, 26 patients (13 male, 13 female; age range 56–90 years, mean age 70.2 years) with *S. pneumoniae* pneumonia combined with *P. aeruginosa* and 22 patients (13 male, 9 female; age range 47–81 years, mean age 71.7 years) with *S. pneumoniae* pneumonia combined with MSSA.

The diagnosis was established by isolation of *S. pneumoniae*, clinical features and pulmonary infiltrates on chest radiographs. *S. pneumoniae* was isolated from sputum of 67 patients, tracheal aspirate of 10 patients, bronchoalveolar lavage fluid of 4 patients and blood specimens of 5 patients. Concurrent infections were diagnosed by the isolation of *H. influenzae*, *P. aeruginosa* or MSSA (Table 2).

A patient was considered to have CAP if, at the time of hospital admission, he/she presented with cough, with or without sputum, fever, leukocytosis or leukopenia, and pulmonary infiltrates on chest radiographs. None of the patients had been admitted to, or treated in, a hospital in the 2 weeks before admission. Of the 86 patients with *S. pneumoniae* pneumonia alone, 53 had CAP and 33 had nosocomial infections. Of the 36 patients with *H. influenzae*, 18 had CAP and 18 had nosocomial infections. Of the 26 patients with *P. aeruginosa*, 7 had CAP and 19 had nosocomial infections, and of the 22 patients with MSSA, 12 had CAP and 10 had nosocomial infections. No patient had HIV infection.

The frequencies of various underlying diseases, alcohol consumption and smoking habits were also evaluated. For the purposes of this study, an alcoholic was defined as an individual with a daily consumption of ≥80 g of alcohol during the past 2 years [15], and a patient was considered to be a heavy smoker if he/she had smoked more than 10 packs of cigarettes per year.

CT examinations

Thin-section CT examinations were performed with 1 mm collimation at 10 mm intervals from the apex of the lung to the diaphragm in 51 patients (26 patients with *S. pneumoniae* alone, 10 with *H. influenzae*, 10 with *P. aeruginosa* and 5 with MSSA), or volumetrically with a multidetector CT system with a 1 mm reconstruction in 119 patients with concurrent pneumonia (n=60, 26, 16 and 17, respectively). CT examinations were performed with the patient in the supine position at full inspiration and were reconstructed using a high-spatial-frequency algorithm. Images were captured at window settings that allowed viewing of the lung parenchyma (window level, –600 to –700 HU; window width, 1200–1500 HU) and the mediastinum (window level, 20–40 HU; window width, 400 HU). The pulmonary CT examination was performed within 1–6 days (mean 3.2 days) after the onset of respiratory symptoms. Intravenously administered contrast material was used for 33 examinations.

Image interpretation

Two chest radiologists (one with 22 and one with 14 years of experience in chest CT image interpretation), who were unaware of the underlying diagnoses, retrospectively and independently interpreted the CT images. Conclusions were reached by consensus.

CT images were assessed for the following radiological patterns: ground-glass attenuation (GGA), consolidation, nodules, centrilobular nodules, bronchial wall thickening, interlobular septal thickening, intralobular reticular opacity, bronchiectasis, enlarged hilar/mediastinal lymph node(s) (>1 cm diameter short axis), cavities and pleural effusion. Areas of GGA were defined as areas showing hazy increases in attenuation without obscuring vascular markings [16, 17]. Areas of consolidation were defined as areas of increased attenuation that obscured the normal lung markings [16, 17]. Centrilobular nodules were

Table 1. The underlying diseases and presenting symptoms in 363 patients

Characteristics	*S. pneumoniae* (n=122)	*S.pneumoniae* with concurrent infections (n=241)	p-value
Smoking habit	38 (31.1)	101 (41.9)	<0.05
Pulmonary emphysema	23 (18.9)	54 (22.4)	NS
Malignancy	23 (18.9)	80 (33.2)	<0.01
Cardiac disease	20 (16.4)	50 (20.7)	NS
Alcoholic	17 (13.9)	71 (29.5)	<0.01
Diabetes mellitus	16 (13.1)	51 (21.2)	NS
Asthma	8 (6.6)	33 (13.7)	<0.05
Liver disorder	8 (6.6)	28 (11.6)	NS
Collagen disease	2 (1.6)	21 (8.7)	<0.01
Presenting symptoms			
Cough	104 (85.2)	187 (77.6)	NS
Sputum	79 (64.8)	222 (92.1)	<0.001
Fever	108 (88.5)	199 (82.6)	NS
Dyspnoea	20 (16.4)	30 (12.4)	NS
Delirium	7 (5.7)	13 (5.4)	NS

NS, not significant.
Data in parentheses are percentages.

Table 2. Characteristics of 170 patients with each type of pneumonia

Characteristics	*S. pneumoniae* (n=86)	*S. pneumoniae* with *H. influenzae* (n=36)	*S. pneumoniae* with *P. aeruginosa* (n=26)	*S. pneumoniae* with MSSA (n=22)
M/F	45/41	27/9	13/13	13/9
Age (year)				
Range	23–98	31–94	56–90	47–81
Mean	61.3	67.2	70.2	71.7
Community acquired	53 (61.6)	18 (50.0)	7 (26.9)	12 (54.5)
Nosocomial	33 (38.4)	18 (50.0)	19 (73.1)	10 (45.5)
Culture sample				
Sputum	67 (77.9)	30 (83.3)	24 (92.3)	20 (90.9)
Tracheal aspirate	10 (11.6)	5 (13.9)	1 (3.8)	1 (4.5)
Bronchoalveolar lavage fluid	4 (4.7)	1 (2.8)	1 (3.8)	1 (4.5)
Blood	5 (5.8)	0 (0)	0 (0)	0 (0)

F, female; *H.*, *Haemophilus*; M, male; MSSA, methicillin-susceptible *Staphyloccus aureus*; *P.*, *Pseudomonas*; *S.*, *Streptococcus*. Data in parentheses are percentages.

defined as those present around the peripheral pulmonary arterial branches or 3–5 mm from the pleura, interlobular septa or pulmonary veins. Interlobular septal thickening was defined as abnormal widening of the interlobular septa [17]. Intralobular reticular opacity was considered present when interlacing line shadows were separated by a few millimetres [16, 17].

The distribution of parenchymal disease was also noted. Whether the abnormal findings were located unilaterally or bilaterally was assessed. If the main lesion was predominantly located in the inner third of the lung, the disease was classified as having a central distribution. Alternatively, if the lesion was predominantly located in the outer third of the lung, the disease was classified as having a peripheral distribution. If the lesions showed no predominant distribution, the disease was classified as having a random distribution. In addition, zonal predominance was classified as upper, lower or random. Upper lung zone predominance meant that most abnormalities were observed at a level above the tracheal carina, while lower zone predominance referred to most abnormalities being below the upper zone. When abnormalities showed no definite zonal predominance, the lung disease was considered to have a random distribution.

Follow-up CT examinations were performed 4 days to 2 months after antibiotic therapy in 44 patients, and follow-up chest radiographs were performed 1 day to 2 months after antibiotic therapy in 110 patients. These follow-up CT images and radiographs were also assessed.

Statistical analysis

Statistical analysis of the frequency of symptoms and CT findings were conducted using Fisher's exact test and the χ^2 test. A mean age comparison was conducted using Student's *t*-test.

Results

Patients' background

The characteristics of all patients are summarised in Table 2. The mean age of the patients with concurrent infection was higher than that of patients with *S. pneumoniae* infection alone. The proportion of patients with nosocomial infection was significantly higher in cases of concurrent *P. aeruginosa* than in cases of *S. pneumoniae* alone ($p<0.005$).

The underlying conditions and presenting symptoms of all patients are summarised in Tables 1 and 3. Among each type of pneumonia, the frequencies of smoking and asthma were significantly higher in patients with *H. influenzae* than in those with *S. pneumoniae* alone ($p<0.005$ and $p<0.005$, respectively; Table 3). The frequencies of malignancy, cardiac disease and alcohol consumption were also significantly higher in patients with *P. aeruginosa* than in those with *S. pneumoniae* alone ($p<0.01$, $p<0.01$ and $p<0.001$, respectively). With respect to presenting symptoms, the frequency of sputum in patients with *H. influenzae* or *P. aeruginosa* was significantly higher than in patients with *S. pneumoniae* alone ($p<0.01$ and $p<0.05$, respectively).

CT patterns

The CT findings of the 170 patients are summarised in Table 4. In the 86 patients with *S. pneumoniae* alone, GGA (n=74, 86.0%) and consolidation (n=65, 75.6%) were most frequently observed, followed by bronchial wall thickening (n=22, 25.6%), centrilobular nodules (n=17, 19.8%) and reticular opacity (n=8, 9.3%; Figure 1). No cavitary lesions were detected in any of the patients.

In the 36 patients with concurrent *H. influenzae*, bronchial wall thickening (n=34, 94.4%) and GGA (n=30, 83.3%) were most frequently observed, followed by centrilobular nodules (n=28, 77.8%) and consolidation (n=26, 72.2%; Figure 2). Bronchiectasis (n=17, 19.4%) and cavity (n=3, 8.3%) were also detected.

The frequencies of bronchial wall thickening and centrilobular nodules were significantly higher in patients with concurrent *H. influenzae*, *P. aeruginosa* or MSSA compared with patients displaying *S. pneumoniae* alone ($p<0.001$ each; Figures 2–4; Table 4). In addition, the frequencies of bronchiectasis were significantly higher in patients with concurrent pathogens compared with those with *S. pneumoniae* alone ($p<0.001$, $p<0.01$ and $p<0.05$, respectively; Figures 2 and 4). Moreover, cavity was more frequently observed in patients with *P. aeruginosa* than in patients with *S. pneumoniae* alone ($p<0.001$; Figure 3).

Table 3. Underlying conditions and presenting symptoms

Underlying conditions	*S. pneumoniae* (*n*=86)	*S. pneumoniae* with *H. influenzae* (*n*=36)	*p*-value	*S. pneumoniae* with *P. aeruginosa* (*n*=26)	*p*-value	*S. pneumoniae* with *MSSA* (*n*=22)	*p*-value
Smoking habit	24 (27.9)	20 (55.6)	<0.005	11 (42.3)	NS	8 (36.4)	NS
Pulmonary emphysema	16 (18.6)	10 (27.8)	NS	3 (11.5)	NS	2 (9.1)	NS
Malignancy	15 (17.4)	11 (30.6)	NS	11 (42.3)	<0.01	4 (18.2)	NS
Cardiac disease	14 (16.3)	8 (22.2)	NS	12 (46.2)	<0.01	4 (18.2)	NS
Alcoholic	12 (14.0)	12 (33.3)	NS	13 (50.0)	<0.001	3 (13.6)	NS
Diabetes mellitus	10 (11.6)	6 (16.7)	NS	4 (15.4)	NS	2 (9.1)	NS
Asthma	3 (3.5)	6 (16.7)	<0.005	2 (7.7)	NS	1 (4.5)	NS
Liver disorder	2 (2.3)	2 (5.6)	NS	2 (7.7)	NS	2 (9.1)	NS
Collagen disease	1 (1.2)	1 (2.8)	NS	4 (15.4)	<0.005	2 (9.1)	<0.05
Presenting symptoms							
Cough	77 (89.5)	34 (94.4)	NS	23 (88.5)	NS	17 (77.3)	<0.05
Sputum	59 (68.6)	34 (94.4)	<0.01	24 (92.3)	<0.05	19 (86.4)	NS
Fever	84 (97.7)	36 (100.0)	NS	25 (96.2)	NS	19 (86.4)	NS
Dyspnoea	17 (19.8)	11 (30.6)	NS	7 (26.9)	NS	4 (18.2)	NS
Delirium	3 (3.5)	3 (8.3)	NS	2 (7.7)	NS	2 (9.1)	NS

H., *Haemophilus*; MMSA, methicillin-susceptible *Staphyloccus aureus*; *P.*, *Pseudomonas*; *S.*, *Streptococcus*.
Data in parentheses are percentages.

Among the three groups of concurrent infections, bronchial wall thickening was more frequently observed in patients with *H. influenzae* than in those with *P. aeruginosa* ($p<0.05$), whereas cavity was more frequently observed in patients with *P. aeruginosa* than in those with *H. influenzae* or MSSA ($p<0.05$ each).

Disease distribution

In the *S. pneumoniae* alone group, abnormal findings were detected unilaterally in 51 patients (59.3%) and bilaterally in 35 patients (40.7%; Table 4). The predominant zonal distribution was the lower zone in 35 patients (40.7%). In the *P. aeruginosa* group, abnormal findings were found unilaterally in 7 patients (26.9%) and bilaterally in 19 patients (73.1%). In the MSSA group, abnormal findings were found unilaterally in 7 patients (31.8) and bilaterally in 15 patients (68.2%). The frequency of bilateral abnormal findings was significantly higher in the groups infected with *P. aeruginosa* or MSSA than in the *S. pneumoniae* alone group ($p<0.005$ and $p<0.05$, respectively). In addition, the frequency of bilateral abnormal findings was higher in the *P. aeruginosa* group than in the *H. influenzae* group. There were no significant differences in zonal distributions among the groups.

Effusion and lymph nodes

Pleural effusion was detected in 16 of the 86 patients infected with *S. pneumoniae* alone (18.6%), and was found

Table 4. Thin-section CT findings for each type of pneumonia

Finding	*S. pneumoniae* (*n*=86)	With *H. influenzae* (*n*=36)	*p*-value	With *P. aeruginosa* (*n*=26)	*p*-value	With MSSA (*n*=22)	*p*-value
Ground-glass attenuation	74 (86.0)	30 (83.3)	NS	26 (100)	NS	18 (81.8)	NS
Consolidation	65 (75.6)	26 (72.2)	NS	20 (76.9)	NS	16 (72.7)	NS
Bronchial wall thickening	22 (25.6)	34 (94.4)	<0.001	20 (76.9)	<0.001	18 (81.8)	<0.001
Centrilobular nodules	17 (19.8)	28 (77.8)	<0.001	20 (76.9)	<0.001	16 (72.7)	<0.001
Interlobular septal thickening	8 (9.3)	3 (8.3)	NS	2 (7.7)	NS	2 (9.1)	NS
Reticular opacity	8 (9.3)	6 (16.7)	NS	3 (11.5)	NS	3 (13.6)	NS
Nodules	7 (8.1)	5 (13.9)	NS	2 (7.7)	NS	3 (13.6)	NS
Bronchiectasis	2 (2.3)	7 (19.4)	<0.001	4 (15.4)	<0.01	3 (13.6)	<0.05
Cavity	0 (0)	1 (2.8)	NS	5 (19.2)	<0.001	0 (0)	NS
Pleural effusion	16 (18.6)	5 (13.9)	NS	16 (61.5)	<0.001	5 (22.7)	NS
Unilateral	11 (12.8)	2 (5.6)	NS	3 (11.5)	NS	2 (9.1)	NS
Bilateral	5 (5.8)	3 (8.3)	NS	13 (50.0)	<0.001	3 (13.6)	NS
Lymph node enlargement	13 (15.1)	4 (11.1)	NS	5 (19.2)	NS	4 (18.2)	NS
Distribution							
Unilateral	51 (59.3)	19 (52.8)	NS	7 (26.9)	<0.005	7 (31.8)	<0.05
Bilateral	35 (40.7)	17 (47.2)	NS	19 (73.1)	<0.005	15 (68.2)	<0.05
Central	10 (11.6)	4 (11.1)	NS	2 (7.7)	NS	2 (9.1)	NS
Peripheral	43 (50.0)	20 (55.6)	NS	17 (65.4)	NS	8 (36.4)	NS
Upper	15 (17.4)	7 (19.4)	NS	4 (15.4)	NS	5 (22.7)	NS
Lower	35 (40.7)	17 (47.2)	NS	9 (34.6)	NS	10 (45.5)	NS

H., *Haemophilus*; MMSA, methicillin-susceptible *Staphyloccus aureus*; *P.*, *Pseudomonas*; *S.*, *Streptococcus*.
Data in parentheses are percentages.

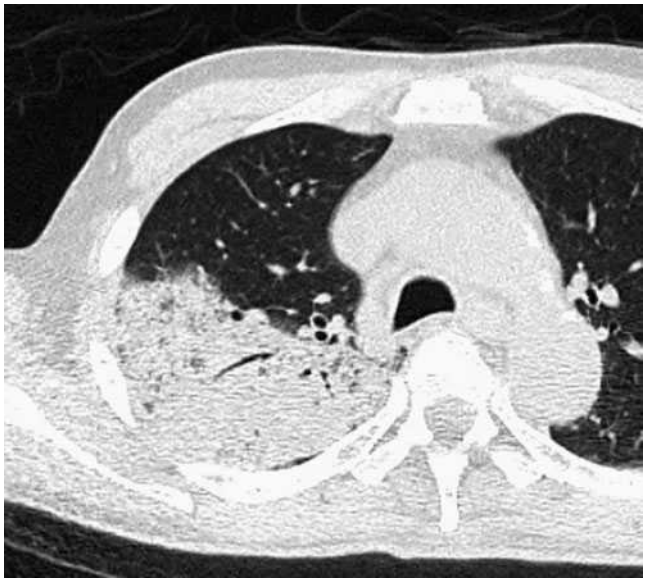


Figure 1. Acute pneumonia caused by *Streptococcus pneumoniae* alone in a 65-year-old male, 3 days after the onset of fever, cough and dyspnoea. Transverse CT image at the level of the right upper lobe shows consolidation.

to be bilateral in 5 patients (5.8%; Table 4). The frequency of pleural effusion was significantly higher in patients with *P. aeruginosa* compared with those with *S. pneumoniae* alone, or with concurrent *H. influenzae* or MSSA ($p<0.001$, $p<0.001$ and $p<0.01$, respectively). In addition, the frequency of bilateral effusion was also significantly higher in patients with *P. aeruginosa* than in those with *S. pneumoniae* alone ($p<0.001$), or with *H. influenzae* ($p<0.001$) or MSSA ($p<0.01$).

Mediastinal and/or hilar lymph node enlargement was observed in 13 patients (15.1%) with *S. pneumoniae* alone, 4 patients (11.1%) with *H. influenzae*, 5 patients (19.2%) with *P. aeruginosa* and 4 patients (18.2%) with MSSA. There were no significant differences among the groups.

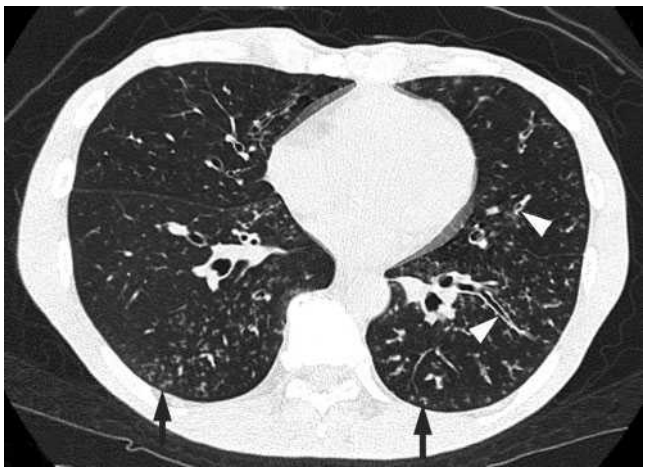


Figure 2. Acute pneumonia caused by *Streptococcus pneumoniae* along with concurrent *Haemophilus influenzae* infection in a 51-year-old male alcoholic with a smoking habit and liver disorder, 3 days after the onset of a cough with sputum and fever. Transverse CT image of the lower lobes shows centrilobular nodules (arrows) and bronchial wall thickening (arrowheads).

Follow-up study

All 170 patients underwent antibiotic therapy. In 83 of the 86 (96.5%) patients with pneumonia caused by *S. pneumoniae* alone, abnormal findings showed improvement on a follow-up CT examination or chest radiography. However, in the remaining three patients (3.5%), abnormal findings were found to worsen on follow-up examinations, and all of these patients subsequently died. In comparison, abnormal findings worsened in 4 of the 36 patients with *H. influenzae* (11.1%), 4 of the 26 patients with *P. aeruginosa* (15.4%) and 2 of the 22 patients with MSSA (9.1%), and these patients died.

The mortality rate among patients with *H. influenzae* or *P. aeruginosa* was significantly higher than among patients with *S. pneumoniae* alone ($p<0.05$ each).

Discussion

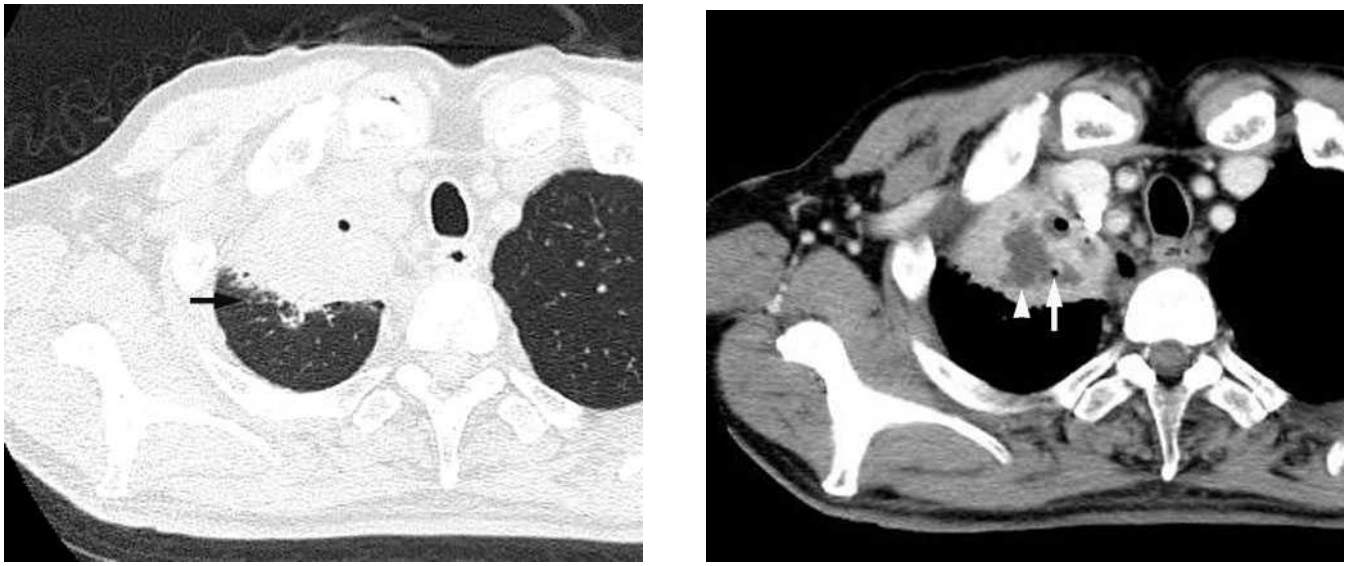
Recent studies have revealed the presence of more than one causative microorganism in a considerable number of CAP and nosocomial pneumonia cases, and the rates for mixed aetiologies range from 2.5% to 79.6% [6, 8, 18]. The relevance of these mixed aetiologies in terms of the clinical outcome and the selection of initial empiric antimicrobial treatment remains to be determined.

It has been reported that in cases of mixed CAP, *S. pneumoniae* was the most prevalent microorganism and severe pneumonia was significantly associated with mixed rather than monomicrobial pneumonia [7, 8, 19].

In the present study, 241 of 363 patients with acute *S. pneumoniae* pneumonia (66.4%) were infected by an additional pathogen. The frequencies of underlying disease were significantly higher in patients with concurrent infections than in patients infected with *S. pneumoniae* alone. It is noteworthy that the frequencies of smoking and asthma were significantly higher in patients with *H. influenzae* than in those with *S. pneumoniae* alone, or concurrently with *P. aeruginosa* or MSSA. This may be explained by the fact that *H. influenzae* is one of the most common organisms found in patients with acute exacerbation of chronic obstructive pulmonary disease and chronic bronchitis [20].

The radiographic features of pneumococcal pneumonia have been described as lobar consolidation or parenchymal opacities [11–13], sometimes associated with pleural effusion [21, 22]. A few studies have reported the CT findings in patients with *S. pneumoniae* pneumonia. Nambu et al [23] compared thin-section CT findings of 41 patients with *S. pneumoniae* pneumonia with those of 24 patients with *Chlamydia pneumoniae* pneumonia. Bronchovascular bundle thickening ($p=0.016$) and airway dilatation ($p=0.034$) were found to be significantly less frequent in patients with *S. pneumoniae* pneumonia than in those with *C. pneumoniae* pneumonia.

However, to the best of our knowledge, no studies comparing CT findings in patients with *S. pneumoniae* pneumonia alone with those with *S. pneumoniae* pneumonia



(a) (b)

Figure 3. Acute pneumonia caused by *Streptococcus pneumoniae* along with concurrent *Pseudomonas aeruginosa* infection in a 73-year-old male alcoholic with cardiovascular disease and prostatic cancer, 4 days after the onset of a cough with sputum and fever. (a) Transverse CT image of right upper lobe shows consolidation and centrilobular nodules (arrow). (b) Enhanced CT image at the same level shows air collection (arrow) and non-enhanced areas (arrowhead).

and concurrent infections have been published. We compared the pulmonary thin-section CT findings of 86 patients with acute *S. pneumoniae* pneumonia alone with those of 84 patients with concurrent *S. pneumoniae* pneumonia. In the patients with *S. pneumoniae* alone, GGA and consolidation were most frequently observed, followed by bronchial wall thickening and centrilobular nodules. These results were similar to those of a previous report describing the CT findings in patients with *S. pneumoniae* pneumonia alone [14]. In the current study, the frequencies of bronchial wall thickening and centrilobular nodules were significantly higher in patients with *H. influenzae*, *P. aeruginosa* or MSSA ($p<0.001$ each) than in patients with *S. pneumoniae* alone. In addition, the frequencies of bronchiectasis were significantly higher in patients with concurrent pathogen compared with *S. pneumoniae* infection alone ($p<0.001$, $p<0.01$ and $p<0.05$, respectively).

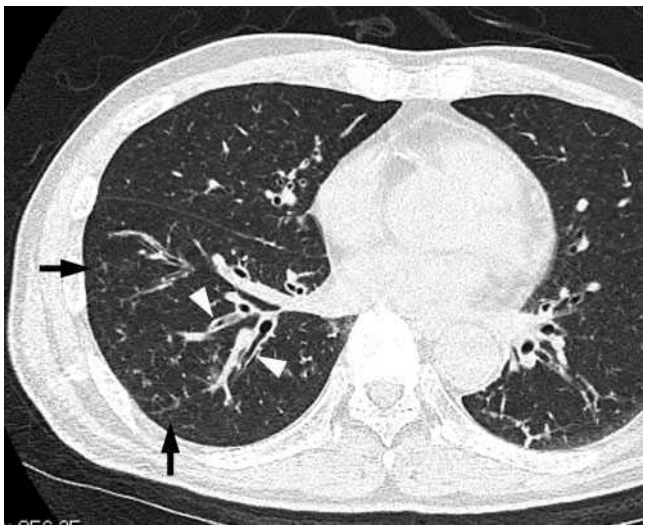


Figure 4. Acute pneumonia caused by *Streptococcus pneumoniae* along with concurrent methicillin-susceptible *Staphylococcus aureus* in a 67-year-old male with a smoking habit, liver disorder and lung cancer, 4 days after the onset of a cough with sputum and fever. Transverse CT image of the right lower lobe shows centrilobular nodules (arrows) and bronchial wall thickening (arrowheads).

Recently, we reported thin-section CT findings in 211 patients with acute *H. influenzae* pulmonary infection who were not infected with any other pathogens [24] and 83 patients with acute MSSA pulmonary infection who were not infected with any other pathogens [25]. The CT findings in the patients infected with *H. influenzae* consisted mainly of bronchial wall thickening (85.8%) and centrilobular nodules (64.9%). Similarly, the CT findings in the patients with MSSA infection consisted mainly of bronchial wall thickening (75.9%) and centrilobular nodules (63.9%). Moreover, we assessed the differences between the thin-section CT findings in 80 patients with acute pneumonia caused by *Klebsiella pneumoniae* alone and those in 25 patients with *K. pneumoniae* pneumonia who were also infected with *P. aeruginosa* [26]. In cases of *K. pneumoniae* pneumonia with *P. aeruginosa*, CT findings of centrilobular nodules, bronchial wall thickening, cavity and pleural effusions were significantly more frequent than in cases of *K. pneumoniae* pneumonia alone ($p<0.001$ each).

H. influenzae, *P. aeruginosa* and MSSA are known to be important pathogens of bronchopneumonia, whereas *S. pneumoniae* causes air space pneumonia. Classified histologically as bronchopneumonia, nodular features would be expected upon CT evaluation of patients with such infections. Pathologically, bronchopneumonia demonstrates inflammatory changes involving the bronchial and bronchiolar walls, with minimal exudation into adjacent alveoli [27]. The thickened walls of bronchiole and peribronchiolar inflammation can contribute to the centrilobular nodules [28]. Therefore, in cases of *S. pneumoniae* infection with concurrent *H. influenzae*, *P. aeruginosa* or MSSA, CT findings

of centrilobular nodules, bronchial wall thickening and bronchiectasis might be significantly more frequent than in cases of *S. pneumoniae* alone.

Cavity was significantly more frequent in patients with *P. aeruginosa* than in patients with *S. pneumoniae* alone, *H. influenzae* or MSSA ($p<0.001$, $p<0.05$ and $p<0.05$, respectively). In patients with *P. aeruginosa*, pleural effusions (especially bilateral) were significantly more frequent than in all the other groups. Furthermore, the bilateral distribution of parenchymal abnormalities was also significantly more frequent in patients with *P. aeruginosa*. Treatment for *P. aeruginosa* infection does not involve initial empiric antibiotic regimens. Therefore, in patients diagnosed with *S. pneumoniae* pneumonia, it is important to determine the radiological differences with and without *P. aeruginosa*. According to the British Thoracic Society guidelines from 2009, CT scanning currently has little role in the routine investigation of CAP [29]. However, in patients diagnosed with *S. pneumoniae* pneumonia, with underlying conditions such as malignancy, cardiac disease or excessive alcohol consumption, CT examinations may be useful to identify concurrent infection, especially with *P. aeruginosa*.

It should be noted that there were several limitations to our study. First, this was a retrospective study and CT image interpretation was performed by consensus. Second, thin-section CT images were obtained using different protocols. Third, CT images in patients with concurrent pathogens other than *H. influenzae*, *P. aeruginosa* and MSSA were not evaluated.

In summary, underlying diseases were significantly more frequent in patients with pneumonia caused by concurrent infections than in those with pneumonia caused by *S. pneumoniae* alone. Our CT findings revealed that centrilobular nodules, bronchial wall thickening and bronchiectasis were significantly more frequent in patients with concurrent *S. pneumoniae* than in those with *S. pneumoniae* alone.

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