Pulmonary Computed Tomography Findings in 39 Cases of *Streptococcus pneumoniae* Pneumonia

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Abstract

Objective The main objective of our study was to describe the pulmonary distribution of consolidation and ground-glass opacity (GGO) in chest computed tomography (CT) scans of *Streptococcus pneumoniae* pneumonia. In addition, the percentage of other pulmonary abnormalities was also reported.

Methods We retrospectively evaluated chest CT examinations performed between November 2008 and January 2010 in 39 patients with *S. pneumoniae* pneumonia. Eight patients with *Haemophilus influenzae* pneumonia were also included for comparison.

Patients There were 19 women and 28 men with clinical symptoms of fever and productive cough and laboratory findings of leukocytosis with markedly high C-reactive protein levels. Chest X-ray scores before and after treatment were calculated. The average score before treatment was 4. The average score after treatment was 0. Parenchymal abnormalities were evaluated along with the presence of enlarged lymph nodes and pleural effusions. The distribution of parenchymal disease was also analyzed.

Results The chest CT findings in the patients with *S. pneumoniae* pneumonia consisted primarily of consolidation (56.4%), ground-glass opacity (71.7%), interlobular reticular opacity (69.2%), centrilobular nodules (53.8%), interlobular septal thickening (46.6%), bronchial wall thickening (46.6%), lymph node enlargement (10.2%) and pleural effusion (10.2%). Segmental distribution (65.7%) was seen more frequently than non-segmental distribution (35.9%). Abnormal findings were noticed bilaterally in 14 patients and unilaterally in 25 patients. On both the right and left sides, predominant zonal distributions were seen in the lower lobes. In contrast, among the eight patients with *H. influenzae* pneumonia, one patient had both segmental and non-segmental distributions and the remaining seven patients had only segmental distributions.

Conclusion In conclusion, segmental distributions of parenchymal abnormalities are more common than non-segmental distributions on chest CT scans of patients with *S. pneumoniae* pneumonia.

Key words: *Streptococcus pneumoniae*, chest X-ray, chest computed tomography, consolidation, segmental distribution, non-segmental distribution

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Introduction

Streptococcus pneumoniae remains the most common causative agent (48% of all cases) of community-acquired pneumonia, followed by viruses (19%), *Haemophilus influenzae* (20%), *Chlamydia pneumoniae* (13%) and *Mycoplasma pneumoniae* (3%) (1, 2). *S. pneumoniae* is a Gram-positive bacterium. Diagnosing pneumonia requires a combination of clinical awareness, appropriate microbiological tests and radiographic analyses. Plain chest radiography is an important initial and inexpensive test that can rapidly detect the presence of pulmonary abnormalities in patients with pneumonia (3-5). However, many studies have indicated that chest computed tomography (CT) is a more sensitive method capable of imaging the lungs with excellent spatial resolution. Performing analyses of pulmonary pathology and various other accompanying abnormalities helps to identify the causes and complications of pneumonia. Unlike chest radiography, chest CT provides cross-sectional images; therefore, the pattern of pulmonary pathology distribution can be appreciated more readily with chest CT than with conventional radiology (6, 7). It has been reported that there are few characteristic features indicative of causative organisms (8-10).

According to various studies, the usual radiological manifestation of *S. pneumoniae* pneumonia includes complete lobar consolidation that involves one segment or lobe with reactive parapneumonic effusion (1, 3). On chest CT, the pulmonary pathology is characteristically represented as a non-segmental pattern of distribution (11, 12). However, in the new era of antibiotics, varied patterns and distributions of infective organisms have been reported (13). Vilar et al. recently reported that pneumococcal pneumonia can appear as patchy, confluent areas that may be multilobular or bilateral (1).

We analyzed the chest CT scans of newly diagnosed *S. pneumoniae* pneumonia patients. The primary aim of our study was to describe the pulmonary distribution of consolidation and ground-glass opacity (GGO). In addition, the percentage of other pulmonary abnormalities was reported. For comparison, we included the chest CT scans of eight patients with *H. influenzae* pneumonia.

Materials and Methods

Patients

This study was conducted as part of a clinical study that evaluated the clinical efficacy of sitafloxacin against *S. pneumoniae* pneumonia. Although the number of patients with *S. pneumoniae* pneumonia was not large, these cases are believed to be very valuable because the patients did not receive prior treatment and the timing of diagnosis and treatment was uniform.

This was a multicenter retrospective study. Between No-

vember 2008 and January 2010, 70 patients were diagnosed with *S. pneumoniae* pneumonia. Thirty-nine cases were selected for chest CT analysis and included in this study. The chest CT scans of eight patients diagnosed with *H. influenzae* pneumonia were included in this study for comparison. Other cases were excluded due to non-availability of CT imaging. The diagnostic criteria for CAP were as follows: 1) acute appearance of consolidation on chest X-ray and/or chest CT within 48 hours prior to treatment, 2) the existence of purulent sputum, 3) an elevated white blood cell count ($>$ normal range) and an increased C-reactive protein (CRP) level (>1.0 mg/dL) and 4) at least one of the following signs or symptoms: i) fever $>37^{\circ}\text{C}$, ii) respiratory distress symptoms (cough, dyspnea or chest pain) and iii) crackles. Other inclusion criteria were as follows: 1) women and men >20 years of age and 2) at least one of the following criteria: i) the presence of Gram-positive diplococci confirmed on Gram stain, ii) *S. pneumoniae* culture of the sputum and iii) a positive urinary antigen test for *S. pneumoniae*.

The diagnosis of *S. pneumoniae* pneumonia was based on a positive urinary antigen test for *S. pneumoniae* and/or a positive culture of *S. pneumoniae* from the sputum. Cases in which respiratory pathogens other than *S. pneumoniae* were cultured from the sputum were excluded. Other exclusion criteria were as follows: 1) patients who required ICU admission or artificial ventilation, 2) patients with known hypersensitivity to fluoroquinolones or other quinolones, 3) patients with a history of epilepsy or underlying convulsive disorders, 4) women who were pregnant or lactating, 5) patients with severe underlying diseases, 6) patients with hepatic dysfunction (AST, ALT $>$ five times institutional normal values), 7) patients with renal dysfunction (serum creatinine >2.0 mg/dL), 8) patients with underlying gastrointestinal diseases such as Crohn's disease, ulcerative colitis or total gastric resection, 9) patients who had received systemic antimicrobial therapy (STFX or azithromycin) for more than 24 hours within 14 days of enrollment and 10) patients receiving newly administered or changed doses of long-term macrolide therapy or corticosteroids (inhaled or oral) within 14 days before treatment. In addition, the final clinical diagnosis of *S. pneumoniae* pneumonia was determined by agreement between JF, AW, NA, YN, JK, KY and SK based on the bacteriological evaluations performed by MK.

The basic clinical features and laboratory findings of the patients are summarized in Table 1. There were 19 women and 28 men. All patients presented with the following symptoms: fever ($>37^{\circ}\text{C}$), cough and sputum. The laboratory data showed leukocytosis ($>10,000/\mu\text{L}$) in 22 patients, and the C-reactive protein levels were abnormally high in all patients with *S. pneumoniae* pneumonia.

Chest X-ray scoring

We also calculated the chest X-ray scores before and after treatment. The average score before treatment was 4.

Table 1. Patient Characteristics and Laboratory Findings

		<i>Streptococcus pneumoniae</i> (n=39)	<i>Haemophilus influenzae</i> (n=8)
Sex	Male	24	4
	Female	15	4
Age (years)		Median: 66 (range: 21-90)	
Temperature (°C)	37.0-37.9	13	5
	38.0-38.9	12	3
	39.0-39.9	11	
	40.0-above	3	
Cough (+)		39	8
Sputum (+)		39	8
WBC (μL^{-1})		Mean: 12,306 (range: 3,200-24,400)	Mean: 11,315 (range: 7,250-12,400)
CRP (mg/dL)		Mean: 12.62 (range: 1.1-38.5)	Mean: 9.25 (3.3-21.4)
Urinary antigen	positive	25	-
	negative	13	-
	not analyzed	1	-

Chest CT analysis

Since this study was performed as a multicenter clinical trial, the scanning machine and scanning conditions were not pre-determined. Chest CT was performed at the time of diagnosis of CAP.

The chest CT scans were analyzed independently by two physicians specialized in pulmonary diseases (FH and JF). The final decisions were made based on the results of both physicians. The inter-observer variability was low. The physicians reviewed hardcopies of the CT images. The images were analyzed with regard to parenchymal lesions, distribution of opacity, internal characteristics of opacity and other findings, including parenchymal lesions such as pleural effusions and lymphadenopathy.

On the CT scans, airspace consolidation was considered to be present when homogeneous increases in pulmonary parenchymal attenuation obscured the margins of the vessels and airway walls (14). The presence of ground glass opacity GGO was defined as hazy increased opacity with preservation of bronchial and vascular markings. The distributions of the airspace consolidations and areas of GGO were subdivided into segmental (bronchopneumonia) and non-segmental (lobar pneumonia) distributions. Segmental opacity manifested as centrilobular nodules with branching linear opacity and airspace nodules with multifocal lobular areas of consolidation. Non-segmental opacity was characterized by the presence of homogeneous airspace consolidations that involved adjacent segments of a lobe. The consolidations tended to be adjacent to the pleura or interlobar fissures.

A centrilobular nodule was defined as a small dot-like opacity in the center of a normal secondary pulmonary lobule most obvious within 1 cm of a pleural surface that represented the intralobular artery. Interlobular septal thickening was defined as abnormal widening of the interlobular septa. Intralobular reticular opacity was considered to be present when interlacing line shadows were separated by a few mil-

limeters.

The distribution of parenchymal disease was also analyzed. If the primary lesion was predominantly located in the inner third of the lungs, the disease was classified as having a central distribution. A peripheral abnormality was defined as an abnormality located in the outer third of the lungs. In addition, zonal predominance was classified as either upper or lower. Upper lung zone predominance meant that the abnormalities were present predominantly above the level of the tracheal carina, whereas lower zone predominance meant that most abnormalities were below the upper zone.

Statistical analysis

Comparisons were made using Student's *t*-test, and *p* values <0.05 were considered to be significant.

Results

CT patterns

Chest CT revealed abnormalities in all patients with *S. pneumoniae* pneumonia. The findings are summarized in Table 2. Among the 39 patients with *S. pneumoniae* pneumonia, GGO was the most common finding (Figs. 1-4). Other common findings included consolidation (Figs. 1, 3, 4), intralobular reticular opacity (Figs. 1-4) and bronchial wall thickening (Figs. 3, 4). In addition, segmental distributions were more common than non-segmental distributions. Segmental distributions were observed in 25 patients (65.7%) (Figs. 1-3), whereas non-segmental patterns were observed in 14 patients (35.9%) (Fig. 4). Interlobular septal thickening (Fig. 3), centrilobular nodules (Figs. 1, 2) and bronchiectasis were also observed. Nodules were seen in 14 patients (35.9%). The combination of consolidation and ground-glass attenuation was seen most frequently (Figs. 1, 3, 4).

Figure 1. *S. pneumoniae* pneumonia in a 53-year-old woman two days after the onset of fever and a productive cough. A chest CT scan showing consolidation (arrow) and ground-glass attenuation with a central distribution. Intralobular reticular opacity (white arrow) and centrilobular nodules were also present. These findings were suggestive of a segmental pattern of distribution.

Figure 2. *S. pneumoniae* pneumonia in an 81-year-old man two days after the onset of fever and a productive cough. A chest CT scan showing ground-glass attenuation (arrow) with a central distribution in the right lobe. Intralobular reticular opacity and centrilobular nodules (white arrow) were also present. These findings were suggestive of a segmental pattern of distribution.

Figure 3. *S. pneumoniae* pneumonia in a 27-year-old man two days after the onset of fever and a productive cough. A chest CT scan showing left lobe consolidation (arrow) and ground-glass attenuation with a central distribution. An air bronchogram, intralobular reticular opacity, bronchial wall thickness (white arrow) and intralobular septal thickening (arrowhead) were also present. These findings were suggestive of a segmental pattern of distribution.

Figure 4. *S. pneumoniae* pneumonia in a 66-year-old man three days after the onset of fever and a productive cough. A chest CT scan showing left lobe consolidation (arrow) and ground-glass attenuation with a central distribution. Intralobular reticular opacity and bronchial wall thickness (white arrow) were also present. A CT scan showing peripheral consolidation and ground-glass attenuation with an air bronchogram on the right side. A pleural effusion was also present.

Of the eight patients with *H. influenzae* pneumonia, consolidation and ground-glass opacity were observed in two cases. Other common findings included centrilobular nodules (87.5%), bronchial wall thickening (100%) and nodules (87.5%). One patient exhibited both segmental and non-segmental distributions, whereas the remaining seven patients exhibited only segmental distributions (Table 2).

Disease distribution

Among the 39 patients with acute *S. pneumoniae* pneumonia, abnormal findings were noticed bilaterally in 14 patients and unilaterally in 25 patients. On both the right and left sides, predominant zonal distributions were seen in the

lower lobes. On the right side, predominant zonal distributions were observed in 18 patients (46.1%), and on the left side, predominant zonal distributions were observed in 21 patients (53.8%). The right upper lobe was affected in 16 patients (41.0%), and the left upper lobe was affected in 10 patients (25.6%). Abnormalities were also noticed in the right middle lobe in 13 patients (37.1%).

Pleural effusion and lymph node enlargement

In addition to parenchymal lesions, pleural effusions were noted in four patients (10.2%) (Fig. 4) with *S. pneumoniae*

Table 2. Thoracic CT Findings in the Pneumonia Patients

Findings	<i>S. pneumoniae</i> (n=39)	<i>H. influenzae</i> (n=8)	p values
Ground-glass attenuation	28 (71.7)	2 (25)	0.0114*
Intralobular reticular opacity	27 (69.2)	2 (25)	0.0186*
Consolidation	22 (56.4)	2 (25)	0.11
Centrilobular nodules	21 (53.8)	7 (87.5)	0.0803
Bronchial wall thickening	18 (46.6)	8 (100)	0.0045*
Interlobular septal thickening	18 (46.6)	0 (0.0)	0.0138*
Nodules	14 (35.9)	7 (87.5)	0.0067*
Pleural effusion	4 (10.2)	0 (0.0)	0.3545
Lymph node enlargement	4 (10.2)	0 (0.0)	0.3545
Bronchiectasis	2 (5.1)	0 (0.0)	0.5232
Cavity	0 (0.0)	0 (0.0)	-
Segmental pattern	25 (65.7)	8 (100)	0.0441*
Non-segmental pattern	14 (35.9)	1 (12.5)	0.2041

The data in parenthesis are percentages.

*p < 0.05

pneumonia. The pleural effusions were bilateral in one patient and unilateral in three patients. Lymph node enlargement was seen in four patients (10.2%). Lymph node enlargement was observed at the paratracheal, tracheobronchial and subcarinal regions.

Follow-up study

All 39 patients with *S. pneumoniae* pneumonia were treated with appropriate antibiotic therapy. In 35 patients with *S. pneumoniae* pneumonia, the abnormal findings were found to have improved on follow-up X-ray examinations. The average pneumonia score on chest X-ray after treatment in these patients was 0. In two patients, bronchiectasis was detected as an underlying disease. In two patients, the symptoms did not improve significantly after treatment. In these patients, the pneumonia scores after treatment were 3 (before treatment =5) and 4 (before treatment =6). In both cases, chest CT was repeated and modification was found to have occurred. In these patients, the consolidations were located peripherally and mixed with GGO, mimicking cryptogenic organizing pneumonia.

Discussion

Pneumonia is the sixth leading cause of death and the first leading cause of death due to infection worldwide (1). Among the types of community-acquired pneumonia, *S. pneumoniae* pneumonia is of great concern due to its tendency to develop antibiotic resistance (15, 16) and its association with high mortality rates in children and the elderly (6). Chest radiography is routinely performed in hospitals for the initial management of patients with pneumonia and is considered to be a reference standard for the diagnosis of community-acquired pneumonia. However, chest radiography does not always reflect the pathological findings of pneumonia due to the summation of opacity, and its reliability is limited by significant inter-observer variability in radiographic interpretation. Recently, with the advent of high-resolution CT, the ability to diagnose diffuse infiltrative diseases has rapidly advanced. More minute findings can be

recognized on chest CT, which can help to differentiate the pathogens that cause pneumonia. In addition, chest CT can confirm the existence of cavitations or other complications (5, 8).

Various studies have been conducted regarding the radiological findings of *S. pneumoniae* pneumonia. Vilar et al. reported that the most common radiological manifestation of *S. pneumoniae* pneumonia is lobar pneumonia involving one segment or lobe (1). The use of antibiotics has changed the appearance of pneumococcal pneumonia. In this study, we analyzed the chest CT scans of 39 recently diagnosed patients with *S. pneumoniae* pneumonia. Airspace infiltrations, including areas of GGO and consolidation with interlobular reticular opacity, were the most common findings on the CT scans. These findings are similar to those of earlier CT studies of *S. pneumoniae* pneumonia (11, 13). In addition, we noted that segmental distributions were more common than non-segmental distributions. To the best of our knowledge, there have been no recent, independent chest CT analyses of the segmental distribution patterns of *S. pneumoniae* pneumonia.

Radiographically, pneumonia is divided into three types: lobar pneumonia, bronchopneumonia and interstitial pneumonia (12). This classification scheme reflects the initial pathological distribution of the inflammatory process. Although *S. pneumoniae* usually presents as non-segmental or lobar pneumonia on CT scans, it is characterized by the presence of homogeneous airspace consolidations involving adjacent segments of a lobe in addition to well-outlined fissures and air bronchograms. The common causative pathogens of lobar pneumonia are *S. pneumoniae*, *Legionella pneumophila* and *Klebsiella pneumoniae*. In contrast, bronchopneumonia is traditionally considered to be segmental in distribution. The CT manifestations of segmental distributions include multifocal lobular consolidations, centrilobular nodules and branching linear opacity and are usually not accompanied by pleural effusions or air bronchograms. The common causes of bronchopneumonia are *Staphylococcus aureus*, Gram-negative organisms, *M. pneumoniae* and fungi.

In a study by Reittner et al. of 114 patients with different types of infectious pneumonia, the most common findings on chest CT in the patients with *S. pneumoniae* pneumonia were airspace consolidation, ground-glass attenuation, centrilobular nodules and reticulations. However, according to that report, the most common pattern of distribution in bacterial pneumonia is non-segmental (11).

Nambu et al. recently reported the chest CT findings of 397 patients with community-acquired pneumonia, including 24 patients with *C. pneumoniae* pneumonia, 41 patients with *S. pneumoniae* and 30 patients with *M. pneumoniae* (13). In that study, it was reported that the most common findings in patients with *C. pneumoniae* pneumonia are consolidation, GGO, bronchovascular bundle thickening and nodules. In addition, it was reported that pulmonary emphysema and airway dilatation are more frequently seen in patients with *S. pneumoniae* pneumonia. Consolidation without bronchovascular bundle thickening is more suggestive of *S. pneumoniae*.

In our study, we also noted that GGO and consolidation were the most common findings, with the combination of these signs being seen in >50% of patients with *S. pneumoniae* pneumonia. On both the right and left sides, pulmonary infiltrates were predominantly located in the lower lobes with segmental distributions. In two patients, consolidation and GGO accompanied by air bronchograms and pleural effusions were the main findings before treatment. These pulmonary lesions were found to be non-segmental in distribution and located bilaterally. On repetition of chest CT after treatment, the consolidations were observed peripherally and had features similar to organizing pneumonia. However, a diagnosis of organizing pneumonia was not confirmed histologically.

In addition, other types of pulmonary lesions, including intralobular reticular opacity, bronchial wall thickening and interlobular septal thickening, were seen in most of the patients. Centrilobular nodules were also a common finding. These pulmonary abnormalities were similar to the chest CT manifestations of *K. pneumoniae* pneumonia. According to a report by Okada et al., the chest CT abnormalities observed in 198 patients with *K. pneumoniae* pneumonia included consolidation and intralobular reticular opacity. However, these findings were predominantly seen in the peripheries of both sides of the lungs (17). The chest CT findings of *M. pneumoniae* pneumonia consist primarily of centrilobular nodules and bronchial wall thickening, the frequencies of which are higher than those in patients with *S. pneumoniae* or *K. pneumoniae* pneumonia (18).

We noted that pleural effusions were accompanied by pulmonary lesions in only four cases. In these cases, the diseases were non-segmental in distribution. Hui et al. recently reported a chest CT analysis of 23 cases of *L. pneumophila* pneumonia (19). In most of the cases, parapneumonic effusions were associated with non-segmental distributions. Considering that segmental lesions are located more adjacent to bronchioles than to pleura, parapneumonic effusions are not

commonly associated with bronchopneumonia. Similar findings were observed in the present study; no segmental distributions were accompanied by pleural effusions.

The importance of segmental distributions in patients with *S. pneumoniae* pneumonia is that they can complicate the course of the pneumonia at any stage. The present study showed that segmental distributions of parenchymal abnormalities are a common finding of *S. pneumoniae* pneumonia in adults. In this study, the chest CT patterns of approximately half of the patients with *Streptococcus pneumoniae* pneumonia demonstrated segmental distributions. Since many pathogens that cause pneumonia show a segmental distribution, there is a less probable chance that an infection is due to pneumococcal pneumonia than if the main CT finding is non-segmental distribution.

Previous work has demonstrated that in patients with *S. pneumoniae* pneumonia, a segmental distribution pattern is frequently observed at the onset of pneumonia (20). However, several hours after the onset of pneumonia, the segmental distribution pattern changes to a non-segmental distribution pattern (20). Therefore, it should be stressed that the timing of radiological evaluation affects the radiological findings.

In the present study, we selected only patients in whom chest CT was performed during the primary clinical prospective study. Since physicians judge the necessity of performing CT after evaluating the patient's condition and X-ray findings in common practice, selection bias towards more severe patients should be considered in this study.

In summary, we investigated CT findings in 39 patients with *S. pneumoniae* pneumonia. The CT findings consisted primarily of consolidation and ground-glass opacity with intralobular reticular opacity and centrilobular nodules. Segmental distributions of parenchymal abnormalities are more frequently observed than non-segmental distributions on the chest CT scans of *S. pneumoniae* pneumonia patients.

The authors state that they have no Conflict of Interest (COI).

References

1. Vilar J, Domingo ML, Soto C, Cogollos J. Radiology of bacterial pneumonia. *Eur J Radiol* **51**: 102-113, 2004.
2. File TMJ. *Streptococcus pneumoniae* and community acquired pneumonia: a cause for concern. *Am J Med* **117** (Suppl 3A): 39S-50S, 2004.
3. Franquet T. Imaging of pneumonia: trends and algorithms. *Eur Respir J* **18**: 196-208, 2001.
4. Boersma WG, Daniels JMA, Löwenberg A, Boeve WJ, Van De, Jagt EJ. Reliability of radiographic findings and the relation to etiological agents in community-acquired pneumonia. *Respir Med* **100**: 926-932, 2006.
5. Sharma S, Maycher B, Eschun G. Radiological imaging in pneumonia: recent innovations. *Curr Opin Pulmo Med* **13**: 159-169, 2007.
6. Niederman MS, Mandell LA, Anzueto A, et al. Guidelines for the management of adults with community acquired pneumonia. Diagnosis, assessment of severity, antimicrobial therapy, and preven-

- tion. *Am J Respir Crit Care Med* **163**: 1730-1754, 2001.
7. Collins J. CT signs and patterns of lung disease. *Radiol Clin North Am* **39**: 1115-1135, 2001.
8. Ito I, Ishida T, Togashi K, et al. Differentiation of bacterial and non-bacterial community-acquired pneumonia by thin-section computed tomography. *Eur J Radiol* **72**: 388-395, 2009.
9. Tanaka N, Matsumoto T, Kuramitsu T, et al. High resolution CT findings in community acquired pneumonia. *J Comput Assist Tomogr* **20**: 600-608, 1996.
10. Dean NC, Bateman KA, Donnelly SM, Silver MP, Snow GL, Hale D. Improved clinical outcomes with utilization of a community acquired pneumonia guidelines. *Chest* **130**: 794-799, 2006.
11. Reittner P, Ward S, Heyneman L, Johkoh T, Müller NL. Pneumonia: high resolution CT findings in 114 patients. *Eur Radiol* **13**: 515-521, 2003.
12. Muller NL, Franquet T, Lee KS. Bacterial pneumonia. In: *Imaging of Pulmonary Infections*. Lippincott Williams and Wilkins, Philadelphia, 2007: 20-28.
13. Nambu A, Saito A, Araki T, et al. *Chlamydia pneumoniae*: comparison with findings of *Mycoplasma pneumoniae* and *Streptococcus pneumoniae* at thin section CT. *Radiology* **238**: 330-338, 2006.
14. Hansell DM, Bankier AA, MacMahon H, McCloud TC, Müller NL, Remy J. Fleischner society: glossary of terms for thoracic imaging. *Radiology* **246**: 697-722, 2008.
15. File TMJ. Appropriate use of antimicrobials for drug resistant pneumonia: focus on the significance of β -lactam resistant *Streptococcus pneumoniae*. *Clin Infect Dis* **34** (Suppl 1): S17-S26, 2002.
16. Musher DM, Dowell ME, Shortridge VD, et al. Emergence of macrolide resistance during treatment of pneumococcal pneumonia. *N Engl J Med* **346**: 630-631, 2002.
17. Okada F, Ando Y, Honda K, et al. Clinical and pulmonary thin-section CT findings in acute *Klebsiella pneumoniae* pneumonia. *Eur Radiol* **19**: 809-815, 2009.
18. Okada F, Ando Y, Wakisaka M, Matsumoto S, Mori H. *Chlamydia pneumoniae* pneumonia and *Mycoplasma pneumoniae* pneumonia: comparison of clinical findings and CT findings. *J Comput Assist Tomogr* **29**: 626-632, 2005.
19. Hui Y, Higa F, Hibiya K, et al. Computed tomographic features of 23 sporadic cases with *Legionella pneumophila* pneumonia. *Eur J Radiol* **74**: e73-e78, 2010.
20. Robertson OH, Coggeshall LT, Terrell EE. Experimental pneumococcus lobar pneumonia in the dog: III. Pathogenesis. *J Clin Invest* **12**: 467-493, 1933.