MAJOR ARTICLE

Changing Bacteriology of Adult Community-Acquired Lung Abscess in Taiwan: *Klebsiella pneumoniae* versus Anaerobes

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(See the editorial commentary by Bartlett on pages 923–5)

Background. Most literature regarding lung abscess focuses on anaerobic bacterial lung abscess, and aerobic gram-negative bacillary infection is less frequently discussed. This study was conducted to investigate the bacteriology of community-acquired lung abscess and to improve the empirical therapeutic strategy for adults with community-acquired lung abscess.

Methods. We reviewed and analyzed data on 90 consecutive adult cases of bacteriologically confirmed community-acquired lung abscess treated during 1995–2003 at a tertiary university hospital in Taiwan.

Results. We found that a high proportion (21%) of cases of lung abscess were due to *Klebsiella pneumoniae* infection, which differs from the findings of previous studies. Lung abscess due to *K. pneumoniae* was associated with underlying diabetes mellitus (odds ratio [OR], 4.3; 95% confidence interval [CI], 1.0–18.4; $P = .039$) and negatively correlated with a time from onset of symptoms to diagnosis of >30 days (OR, 0.2; 95% CI, 0.1–0.7; $P = .008$). A higher percentage of patients with *K. pneumoniae* lung abscess had concomitant bacteremia (OR, 9.4; 95% CI, 1.1–81.9; $P = .032$), delayed defervesence (OR, 9.2; 95% CI, 1.8–47.8; $P = .004$), and multiple cavities noted on radiographs (OR, 11.0; 95% CI, 1.3–94.9; $P = .015$), compared with patients with anaerobic bacterial lung abscess. The rate of nonsusceptibility to clindamycin and penicillin among anaerobes and *Streptococcus milleri* group isolates increased.

Conclusion. *K. pneumoniae* has become a more common cause of lung abscess than before, and a high proportion of anaerobes and *S. milleri* strains have become resistant to penicillin and clindamycin. A β-lactam/β-lactamase inhibitor or second- or third-generation cephalosporin with clindamycin or metronidazole is suggested as empirical antibiotic therapy for community-acquired lung abscess.

Most lung abscesses occur in patients with a predisposition to aspiration and systemic or local immunocompromised status, such as chronic lung disease, malignancy, or diabetes mellitus [1, 2]. Oropharyngeal anaerobes and microaerophilic streptococci have been the predominant pathogens involved in lung abscesses, causing 85%–93% of cases in published reports [2]. Other aerobic bacteria that cause lung abscess were substantially less common [1–3]. Aerobic gram-negative bacilli, which are often implicated in hospital-acquired cases of lung abscesses, were associated with a poor prognosis in some small studies [3–5]. Diagnostic methods uncontaminated with colonizing bacteria from the upper airway, such as transtracheal aspiration, transthoracic lung aspiration, or thoracocentesis from empyema fluid, make isolation of both aerobic and anaerobic bacteria possible [1, 2]. Because transtracheal or transthoracic lung aspiration is seldom used as a result of a lack of skilled physicians, lung abscesses rarely have an etiological diagnosis [2].

In recent years, the problem of antibiotic resistance (including resistance among anaerobic bacteria) has become common. Clindamycin and penicillin, which were previously the standard treatment for anaerobic bacterial lung abscess in relatively few clinical trials [6–8], have not been effective against some anaerobes in recent years [9, 10]. To make an effective recommendation for empirical therapy for adults with commu-

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nity-acquired lung abscess, especially for patients who did not receive a diagnosis based on invasive procedures, we evaluated the epidemiological features and antibiotic susceptibility test results for 90 consecutive, bacteriologically confirmed cases of community-acquired lung abscess from 1996 through 2003 at National Taiwan University Hospital (Taipei, Taiwan).

PATIENTS, MATERIALS, AND METHODS

Patient selection. Data for all adults (age, >18 years) who received a diagnosis of lung abscess (*International Classification of Diseases, Ninth Revision,* code 513) during 1996–2003 at National Taiwan University Hospital, a tertiary care university hospital in northern Taiwan, were found by computer registry system. The diagnosis was reconfirmed by 1 pulmonary specialist and 1 infectious diseases specialist. Patients were included in the study if they met all of the following 3 criteria: (1) symptoms of pulmonary infection, such as fever and cough, were present; (2) a cavity was seen on a chest radiograph ⩽72 h after hospital admission, or a lung mass without a cavity was seen on a radiograph ⩽72 h after hospital admission, with a lung abscess seen during a surgical procedure or histopathological examination; and (3) documented bacteriological data from an uncontaminated specimen were available. Uncontaminated specimens included lung tissue samples obtained from percutaneous ultrasonography-guided or CT-guided transthoracic needle aspiration; intraoperative specimens obtained during open-lung biopsy; positive pleural effusion culture specimens; positive blood culture specimens, if pulmonary infection was the only likely portal of entry for blood culture isolates; and concurrent positive blood culture and respiratory specimen cultures with the same pathogen isolated. Specimens of expectorated sputum or washing fluid from bronchoscopic examinations with positive results were not regarded as uncontaminated specimens.

Patients were excluded for any one of the following reasons: there was no documented bacteriological result from examination of uncontaminated lung tissue or from pleural effusion or blood culture; the lung abscess was nosocomial; the chart record was incomplete; or the lung abscess was due to a nonbacterial pathogen (i.e., a parasite, fungus, or mycobacterium). Nosocomial lung abscess was defined as an abscess cavity noted by radiographic examination ⩾72 h after hospital admission [11].

Data collection. The following data were collected for each patient: age, sex, predisposing factors, clinical symptoms, the interval from the onset of symptoms to presentation, initial hemogram and biochemistry values, antibiotics used before culture samples were obtained, bacteria yielded by culture of sterile specimens, duration of hospitalization and of antibiotic therapy for lung abscess, surgical interventions, and outcomes. Predisposing factors included a history of choking and/or aspiration, chronic lung disease, bronchial obstruction secondary to cancer, and other major comorbidities, such as diabetes mellitus, chronic liver disease, CNS disease, and immunocompromised state. Alcoholism, altered mental status, structural abnormalities of the pharynx and esophagus, neuromuscular disorders, and deglutition abnormalities were considered to be risk factors for choking and/or aspiration. Chronic liver disease was defined as a known history of chronic hepatitis or cirrhosis. Bronchial obstruction was defined as bronchial stenosis due to malignancy or other chronic inflammation demonstrated by bronchoscopy. Poor clinical outcomes included delayed defervesence, respiratory failure, shock, and death that was directly attributable to lung abscess. Delayed defervesence was defined as body temperature of >38°C after >7 days of therapy with effective antibiotics.

Microbiology laboratory procedures. The methods and eligibility criteria for performance of transthoracic lung aspiration were described in a previous report [12]. Transthoracic aspirate specimens were collected in airtight, oxygen-free syringes and were immediately sent to the laboratory for aerobic and anaerobic microbial cultures, and isolates from cultures were identified by standard aerobic and anaerobic microbial identification methods. Specimens from every percutaneous aspiration of lung tissue was also sent for mycobacterial, fungal, and cytological examination. The antimicrobial susceptibility of common aerobes was tested by the disk diffusion method, and the antimicrobial susceptibility of anaerobes was tested by an agar dilution method, in accordance with guidelines of the NCCLS [13]. The antimicrobial agents used for susceptibility testing of anaerobic bacteria included penicillin, ampicillin-sulbactam, clindamycin, metronidazole, and cefoxitin. An inoculum of 10^5 colony-forming units/well was applied with a

Table 1. Demographic and clinical characteristics of patients with community-acquired lung abscess.

Characteristic	Value (n = 90)
Age, mean years ± SE	59.0 ± 15.1
Male sex	73 (81)
Underlying disease or risk factor	
Smoking	51 (57)
Chronic lung disease	33 (37)
Chronic liver disease	10 (11)
CNS disease	10 (11)
Malignancy	17 (19)
Diabetes mellitus	28 (31)
Aspiration	29 (32)
Alcoholism	13 (14)
Steroid use	5 (6)
None	16 (18)

NOTE. Data are no. (%) of patients, unless otherwise indicated.

Steers replicator onto *Brucella* agar supplemented with vitamin K_1 and 5% pooled sheep blood. Plates were incubated in an anaerobic chamber for 48 h at 35°C. The proportions of susceptible, intermediate, and resistant isolates were determined by using the NCCLS breakpoints. Reference strains of *Bacteroides fragilis* ATCC 25285 and *Bacteroides thetaiotaomicron* ATCC 29741 were used for quality control of the susceptibility tests.

Statistics. Contingency data were analyzed by 2-tailed χ^2 test or Fisher's exact test, and continuous data were analyzed by Student's *t* test or the Mann-Whitney *U* test. A *P* value of <.05 was considered to be statistically significant, and all probabilities were 2-tailed. All statistical analyses were performed with SPSS, version 10.0 for Windows (SPSS).

RESULTS

Patient characteristics, risk factors, and clinical features. During the study period, there were a total of 336 cases of lung abscess, and 120 cases had documented bacteriological results from lung tissue, pleural effusion, or blood cultures. Of these 120 cases, 90 were classified as community acquired, and 30 were classified as nosocomial lung abscesses. Detailed data from these 90 cases of community-acquired lung abscess were included in the analysis.

Of 90 cases, 73 involved male patients, and 17 involved female patients. One patient with lung abscess due to *Klebsiella pneumoniae* had a recurrent lung abscess in a different pulmonary lobe 1 year after the initial infection. The diagnostic methods used for bacteriology-confirmed lung abscesses included percutaneous transthoracic aspiration, in 59 cases (66%; ultrasonography-guided in 56 cases and CT-guided in 3); positive blood culture results, in 16 (18%); positive pleural effusion culture results, in 19 (21%); and examination of surgical specimens, in 8 (9%). Single lung abscess occurred in 72 (80%) of 90 patients, and multiple cavities seen on radiographs occurred in 18 patients (20%). Most patients had an underlying disease or predisposing factor (table 1). Bronchoscopy was performed for 50 (56%) of the 90 patients. Seventeen patients had an underlying malignancy, including 11 patients with bronchogenic carcinoma; 10 of these 11 patients had postobstructive lung abscess, and 2 of the 11 had malignant cells found in the abscess. Four cases were new diagnoses of lung cancer during hospitalization for lung abscess. Other malignancies ($n = 6$) included esophageal cancer ($n = 2$), gastric cancer ($n = 1$), skin cancer with lung metastasis ($n = 1$), nasopharyngeal cancer ($n = 1$), and multiple myeloma ($n = 1$).

Bacteriological characteristics and relationship with clinical characteristics. In total, 118 bacteria pathogens were recovered from 90 patients (table 2). Nineteen (21%) of the 90 cases were polymicrobial, and 71 (79%) were monobacterial. Of the 118 pathogens identified, *K. pneumoniae* was the most common isolated pathogen, followed by *Streptococcus milleri* group. A higher proportion of pure cultures yielded gram-negative bacilli (35 [83%] of 42 cultures) and gram-positive cocci (21 [68%] of 31) than anaerobes (12 [30%] of 40). *K. pneumoniae* (28 [38%] of 73) and *S. milleri* group (12 [16%] of 73) were also

Table 2. Bacteriological findings for 90 cases of community-acquired lung abscess.

Isolate(s), by class	No. of isolates identified/no. isolated in pure culture
All	118/73
Anaerobes	
All	40/12
Peptostreptococcus species[a]	11/2
Prevotella species[b]	8/2
Bacteroides species	6/1
Unidentified anaerobes	
Gram negative	4/3
Gram positive	3/2
Fusobacterium species[c]	3/0
Propionibacterium acne	2/1
Porphyromonas asaccharolytica	1/0
Veillonella species	1/0
Clostridium perfringens	1/1
Gram-positive cocci	31/21
Streptococcus milleri[d]	19/12
Viridans streptococci	5/4
Group A or B streptococci	3/3
Staphylococcus aureus	2/2
Enterococcus faecalis	1/0
Pediococcus species	1/0
Gram-negative bacilli	
All	42/35
Klebsiella pneumoniae	30/28
Pseudomonas aeruginosa	1/0
Haemophilus influenzae	3/3
Eikenella corrodens	3/2
Escherichia coli	3/1
Burkholderia pseudomallei	1/1
Haemophilus parainfluenzae	1/0
Gram-positive bacilli	
All	5/5
Nocardia asteroides	4/4
Rhodococcus equi	1/1

[a] *Peptostreptococcus* species included *Peptostreptococcus anaerobius* ($n = 2$), *Peptostreptococcus micros* ($n = 2$), and unidentified *Peptostreptococcus* species ($n = 7$).
[b] *Prevotella* species included *Prevotella buccae* ($n = 2$), *Prevotella intermedia* ($n = 2$), *Prevotella melaninogenicus* ($n = 1$), and unidentified *Prevotella* species ($n = 3$).
[c] *Fusobacterium* species included *Fusobacterium necrophorum* ($n = 1$) and *Fusobacterium nucleatum* ($n = 2$).
[d] *Streptococcus milleri* group included *Streptococcus constellatus* ($n = 15$) and *Streptococcus intermedius* ($n = 4$).

Table 3. Comparison of clinical presentations among patients with community-acquired lung abscesses, according to bacteriological class of the pathogen(s) isolated.

Finding	Patient group, by class of pathogen					All patients (n = 90)
	Aerobic GNB (n = 37)	Aerobic GPC (n = 20)	Anaerobes (n = 18)	Mixed (n = 10)	Aerobic GPB (n = 5)	
Presentation finding						
Duration of symptoms of >30 days	14 (38)	11 (55)	13 (72)	4 (40)	2 (40)	44 (49)
Putrid sputum	1 (3)	3 (15)	5 (28)	2 (20)	0 (0)	11 (12)
Cough						
Productive	24 (65)	15 (75)	14 (78)	8 (80)	4 (80)	65 (72)
Dry	7 (19)	3 (15)	2 (11)	2 (20)	1 (20)	15 (17)
Hemoptysis	14 (38)	7 (35)	6 (33)	2 (20)	1 (20)	30 (33)
Chest pain	10 (27)	7 (35)	0 (0)	2 (20)	2 (40)	21 (23)
Dyspnea	7 (19)	3 (15)	2 (11)	2 (20)	1 (20)	15 (17)
Multiple cavities on initial chest radiograph[a]	13 (35)	2 (10)	1 (6)	1 (10)	0 (0)	17 (19)
Initial laboratory value, mean ± SE						
Hemoglobin, g/dL	11.5 ± 2.1	11.5 ± 1.4	11.5 ± 1.5	10.4 ± 2.1	11.5 ± 1.5	11.4 ± 1.8
Leukocyte count, $\times 10^3$ cells/mm^3	13.6 ± 6.6	15.5 ± 8.5	13.0 ± 3.9	13.0 ± 4.3	11.8 ± 3.4	13.8 ± 6.3
Neutrophils, %	84 ± 10	83 ± 7	76 ± 12	78 ± 12	84 ± 7	81 ± 10
Albumin, mg/dL	2.7 ± 0.6	2.8 ± 0.4	3.1 ± 0.7	2.5 ± 0.7	2.8 ± 0.7	2.8 ± 0.6
Positive blood culture results	11 (30)	2 (10)	1 (6)	2 (20)	0 (0)	16 (18)
Concurrent empyema	10 (27)	3 (15)	1 (6)	4 (40)	1 (20)	19 (21)
Antibiotic use >3 days before culture	9 (24)	5 (25)	4 (22)	3 (30)	2 (40)	23 (26)

NOTE. Data are no. (%) of patients, unless otherwise indicated. GNB, gram-negative bacilli; GPB, gram-positive bacilli; GPC, gram-positive cocci.
[a] $P < .05$.

the most common pathogens in patients with monobacteric lung abscess. Of the aerobic and facultative gram-positive cocci, viridans streptococci (especially *S. milleri* group) were the predominant pathogens. Of the anaerobes, *Peptostreptococcus* species, *Prevotella* species, and *Bacteroides* species predominated. The isolates from the 90 culture-positive cases were categorized into the following groups: pure aerobic gram-negative bacilli (n = 37); pure aerobic or facultative gram-positive cocci (n = 20); pure anaerobes (n = 18); pure gram-positive bacilli (n = 5), and mixed isolates (n = 10). The clinical characteristics of the patients with infections from these 5 categories are shown in table 3. Twelve percent of patients presented with putrid sputum. Patients with cases from the pure anaerobic group were more likely to have a subacute or chronic presentation (duration of presenting symptoms before diagnosis, >30 days) than were others (72% vs. 43%; $P < .05$). Patients with cases in the gram-negative bacilli category had a higher prevalence of multiple cavities than did others ($P < .05$).

Susceptibility testing. The susceptibility data for 40 anaerobic bacteria isolated from patients with community-acquired lung abscess were as follows: for penicillin, 15% of isolates were resistant, and 5% were intermediate; for clindamycin, 5% were resistant, and 2.5% were intermediate; for metronidazole, 5% were resistant, and 2.5% were intermediate; for cefoxitin, 2.5%

Table 4. Comparison of outcomes for patients with community-acquired lung abscesses, according to bacteriological class of the pathogen(s) isolated.

Variable	Patient group, by class of pathogen					All patients (n = 90)
	Aerobic GNB (n = 37)	Aerobic GPC (n = 20)	Anaerobes (n = 18)	Mixed (n = 10)	Aerobic GPB (n = 5)	
Duration of hospital stay, mean days ± SE	31.3 ± 18.3	26.2 ± 13.9	18.9 ± 8.7	33.7 ± 32	35.6 ± 14.5	26.2 ± 13.9
Surgery	5 (14)	1 (5)	3 (17)	3 (30)	2 (40)	14 (16)
Intubation	6 (16)	2 (10)	0 (0)	2 (20)	0 (0)	10 (11)
Death	4 (11)	0 (0)	1 (6)	1 (10)	0 (0)	6 (7)

NOTE. Data are no. (%) of patients, unless otherwise indicated. GNB, gram-negative bacilli; GPB, gram-positive bacilli; GPC, gram-positive cocci.

Table 5. Comparison between characteristics of patients with lung abscesses due to *Klebsiella pneumoniae* and those with lung abscesses due to anaerobes.

Characteristic	Patient group, by class of pathogen		*P*
	Anaerobes (*n* = 18)	*K. pneumoniae* (*n* = 28)	
Age, mean years ± SE	59.8 ± 15.2	58.7 ± 15.0	.790
Sex, no. of male/female	12/6	24/4	.157
Pulmonary cavities			
Multiple cavities	1 (6)	11 (39)	.015
Cavity in upper lobe	7 (47)[a]	14 (50)	1.000
Large cavity[b]	0 (0)	3 (11)	.270
Predisposing condition or risk factor			
Aspiration	4 (22)	10 (36)	.332
Alcoholism	1 (6)	7 (25)	.124
Chronic lung disease	4 (22)	14 (50)	.060
Liver disease	2 (11)	6 (21)	.453
Malignancy	4 (19)	6 (21)	1.000
Diabetes	3 (17)	13 (46)	.039
Immunocompromise	1 (6)	0 (0)	.391
Bronchial obstruction	4 (22)	4 (14)	.693
Symptom			
Putrid sputum	5 (28)	0 (0)	.006
Dry cough	0 (0)	10 (36)	.004
Peak temperature on day 1, mean °C ± SE	38.1 ± 1.0	38.4 ± 0.9	.578
Duration of illness, mean days ± SE	83.7 ± 85.7	37.3 ± 70.6	.206
Chronic symptoms[c]	13 (72)	9 (32)	.008
Antibiotic use >3 days before culture	4 (22)	7 (25)	1.000
Diagnostic method			
Bronchoscopy performed	12 (52.2)	16 (57.1)	.509
Positive percutaneous aspirate culture result	13 (72.2)	16 (57.1)	.301
Positive blood culture result	1 (5.6)	10 (35.7)	.032
Positive plural effusion culture result	1 (5.6)	7 (25.0)	.089
Outcome			
Defervescence after 7 days[d]	2 (11.1)	15 (53.6)	.004
Respiratory failure	0 (0)	5 (17.9)	.140
Shock	1 (5.6)	3 (10.7)	1.000
In-hospital death	1 (5.6)	2 (7.1)	.831

NOTE. Data are no. (%) of patients, unless otherwise indicated.

[a] Data are for 17 pathogens; 1 case of anaerobic lung abscess involved both the upper and lower lobe.
[b] Size, >6 cm.
[c] Duration, >30 days.
[d] After initiation of antimicrobial therapy.

were resistant; for ampicillin-sulbactam, 2.5% were resistant. Of 30 isolates of *K. pneumoniae,* all were resistant to ampicillin, 1 (3%) had intermediate resistance to cefazolin, 1 (3%) had intermediate resistance to amoxicillin-clavulanate, and all were susceptible to second- and/or third-generation cephalosporins, gentamicin, and ciprofloxacin. Of 19 isolates from the *S. milleri* group, 21% were resistant to clindamycin, and 11% were resistant to penicillin.

Treatment and outcome. For 57 (63%) of the 90 patients, a β-lactam/β-lactamase inhibitor, with or without gentamicin, was used as empirical therapy. Eighteen (20%) of 90 patients received a second-/third-generation cephalosporin, with or without gentamicin. Six (9%) received a second-/third-generation cephalosporin, with clindamycin or metronidazole. Four patients (4%) received clindamycin or penicillin alone. Two patients received penicillin plus gentamicin. Two patients did not receive antibiotics initially, and 1 patient with a history of β-lactam allergy received fluoroquinolone and metronidazole initially. Twelve (13%) of 90 patients received inappropriate or inadequate initial antibiotic therapy, including 3 patients with

anaerobic bacterial infection who received cephalosporins with no activity against anaerobes, 2 patients with streptococcal lung abscess who received antituberculosis agents alone, and 7 patients who received empirical antibiotics that did not have efficacy against the isolated pathogen (*Nocardia asteroides* infection in 4 patients, and *B. gracilis, Pseudomonas aeruginosa,* and *Burkholderia pseudomallei* infection in 1 patient each). Fourteen patients underwent surgery for lung abscess. The clinical outcomes are shown in table 4. Six of 90 patients died of uncontrollable lung abscess.

Comparison between* K. pneumoniae *and anaerobes. Since *K. pneumoniae* was the most commonly isolated pathogen in this study, the characteristics of the patients with pure *K. pneumoniae* lung abscess were compared with those who had lung abscesses due to anaerobes (table 5). Patients with *K. pneumoniae* lung abscess had a higher prevalence of diabetes mellitus than did patients infected with anaerobes (46% vs. 17%; OR, 4.3; 95% CI, 1.0–18.4; $P = .039$). The 2 groups did not differ with regard to underlying predisposing conditions of aspiration, alcoholism, malignancy, CNS dysfunction, and chronic liver or renal disease, although patients with *K. pneumoniae* abscesses presented less often with the subacute or chronic form (32% vs. 72%; OR, 0.2; 95% CI, 0.1–0.7; $P = .008$) and with putrid sputum (0% vs. 28%; $P < .05$), but they presented more often with dry cough (36% vs. 0%; $P < .05$). Regarding laboratory data, patients with *K. pneumoniae* lung abscess had a higher rate of positive blood culture results (36% vs. 6%; OR, 9.4; 95% CI, 1.1–81.9; $P = .032$), a higher percentage of neutrophils in peripheral blood (mean ± SE, 85.9% ± 6.0% vs. 76.0% ± 11.7%; $P < .05$), and higher serum blood urea nitrogen levels (mean ± SE, 24.0 ± 20.2 mg/dL vs. 13.8 ± 6.5 mg/dL; $P < .05$). The creatinine level did not differ. On chest radiographs, lung abscesses due to *K. pneumoniae* did not differ in location or cavity size but more often had multiple cavities than did lung abscesses due to anaerobes (39% vs. 6%; OR, 11.0; 95% CI, 1.3–94.9; $P = .015$). Patients who had *K. pneumoniae* lung abscesses had a higher incidence of defervesence at >7 days after commencement of effective antibiotic therapy (54% vs. 11%; OR, 9.2; 95% CI, 1.8–47.8; $P = .004$) and were more likely to have had respiratory failure or septic shock, but the latter was not found to be statistically significant. This study revealed only 1 concurrent lung and liver abscess (4%) among 28 cases of *K. pneumoniae* lung abscess. Two of 28 cases of lung abscess due to *K. pneumoniae* presented with cavity development after initial pneumonia presentation.

DISCUSSION

Previously, there have been few bacteriological studies of lung abscess because of the relative infrequency of this disease and the difficulty in obtaining appropriate specimens for anaerobic culture [2]. This large study of bacteriologically confirmed, community-acquired cases of lung abscess in adults provides information about the distribution of causes, susceptibility pattern, and clinical features for different pathogens. *K. pneumoniae* was found to be the most common cause in this study, which had different findings from the classic studies that report anaerobic bacteria as the predominant etiology.

Lung abscesses due to *K. pneumoniae* were reported in small studies before the 1970s [14–16]. In recent study of lung abscess with diagnostic methods that were uncontaminated with bacteria from the upper airway, *K. pneumoniae* accounted for <5% of these infections [12, 17, 18]. Since the 1990s, distinctive infections involving community-acquired *K. pneumoniae* bacteremia, with liver abscess, endophthalmitis, and meningitis, have emerged as substantial public health problems in Taiwan [19–21]. There have also been several case reports of *K. pneumoniae* lung abscess with concurrent infection that occurred at other sites or developed after pneumonia published from India, Spain, Japan, and Korea in recent years [22–26]. *K. pneumoniae* was the most common pathogen in a study of community-acquired liver abscess, meningitis, prostatitis, and thoracic empyema in Taiwan after the 1990s [21, 27-30]. More than 50% of *K. pneumoniae* lung abscesses in this study were not secondary to bacteremia or other foci of infections. Among all bacterial isolates recovered from transthoracic aspirates in different periods in our institution, the proportion of *K. pneumoniae* isolates increased from 4.6% (3 of 65 isolates) for the period 1985–1990 [12] to 21% (16 of 76) for 1996–2003. In previous studies, some patients were found to have pharyngeal colonization with gram-negative bacilli. Among alcoholics and diabetic patients, this may contribute to the propensity to pneumonia due to gram-negative pathogens [31–33]. These findings imply that both aspiration of *K. pneumoniae* from a colonized oropharyngeal tract into the lower respiratory tract and secondary bacteremia are important in the pathogenesis of lung abscess due to *K. pneumoniae.*

Diabetes mellitus (46%) was an important risk factor associated with *K. pneumoniae* lung abscess in this study, but prevalences of other reported predisposing factors for *K. pneumoniae* infection, such as alcoholism [14–16], did not differ between patients with a lung abscess due to *K. pneumoniae* and those with a lung abscess due to other pathogens. Approximately 50% of community-acquired *K. pneumoniae* infections (other than lung abscesses) in Taiwan were found to be associated with diabetes mellitus [19–21, 27]. In the preantibiotic period, thick sputum, small hemoptysis, formation of multiple thin-walled cavities after acute or subacute pneumonia, and high mortality rates were described in association with *K. pneumoniae* lung abscess [15, 16]. Many of the patients with *K. pneumoniae* lung abscess in our study did not have stages of consolidation before abscess formation. The prevalence of multiple cavities with variable degree of pneumonitis around cav-

itations in *K. pneumoniae* lung abscess in our study was similar to that in other reports [15, 16, 26]. In previous studies of anaerobic bacterial pulmonary infection, 90% of patients were afebrile within 7 days after commencement of antibiotic therapy [1]. In this study, patients with *K. pneumoniae* lung abscess were less likely to have controlled fever 7 days after commencement of therapy than were patients with lung abscess due to anaerobes (53.6% vs. 11.1%; $P < .05$).

The increased resistance to antibiotics among both anaerobes and *S. milleri* group isolates was another important finding of the present study. The better response to treatment and the greater susceptibility of anaerobes to clindamycin than to penicillin made clindamycin a better choice for treatment of anaerobic lung abscess [6]. However, monotherapy with clindamycin seems unsuitable as empirical treatment for lung abscess because of a high rate of resistance to clindamycin (20%) among *S. milleri* group pathogens and a lack of activity against gram-negative bacilli. Capsular material produced by *S. milleri* group pathogens might be a pathogenic factor in lung abscess [34]. A high percentage of clindamycin-resistant *S. milleri* group strains has not been reported previously [35, 36]. A β-lactam/β-lactamase inhibitor or cephalosporin plus clindamycin or metronidazole seems to be a reasonable therapeutic recommendation for empirical therapy. Recently, 2 trials reported that β-lactams/β-lactamase inhibitors (either ampicillin-sulbactam or amoxicillin-clavulanate) were well tolerated and effective for the treatment of aspiration pneumonia and lung abscess [37, 38].

In this study, use of transthoracic lung aspiration, in combination with pleurocentesis and blood culture, led to updated knowledge about the bacteriological characteristics of community-acquired lung abscess. Transthoracic ultrasonography-guided aspiration for detection of cavitary lung lesions has been performed at our institution since the 1990s [12, 39]. In most bacteriological studies of lung abscesses, transtracheal aspiration and protected bronchial brushing were the most common procedures for collection of uncontaminated specimens [1–3]. Two other studies, which were published in the 1990s, used percutaneous transthoracic lung aspiration for microbiological diagnosis [17, 18]. There are no guidelines for diagnosis of lung abscess with use of invasive procedures; however, most experts recommend use of invasive diagnostic procedures only when there is lack of early response to therapy [2, 3, 18]. Less common pathogens, such as *Nocardia asteroids, Rhodococcus equi, Eikenella corrodens,* and some multidrug-resistant bacteria, can be isolated from transthoracic lung aspirate specimens successfully, which can guide antibiotic therapy.

A limitation of this retrospective study is that nearly one-quarter of patients had used antibiotics for >3 days before cultures were performed. Some bacteria, especially anaerobes, may not be isolated successfully after receipt of antibiotic treatment [2]. Use of antibiotics before transthoracic aspiration in some cases, classification of *S. milleri* group pathogens as "non-anaerobes," and geographical factors—namely, that *K. pneumoniae* infection is highly endemic in Taiwan [19]—may explain why fewer anaerobes were isolated in this study than in the studies reported in the literature [1–3, 7]. However, there was no difference in the duration of antibiotic use before isolation of a pathogen among patients in the different bacteria categories. Selection bias in this study may have occurred, because nearly two-thirds of patients who received a diagnosis of lung abscess by computer registry system did not have bacteriological study results available, and data for these patients were excluded.

In conclusion, *K. pneumoniae* should be considered as a possible etiological agent, in addition to anaerobes, in cases of community-acquired lung abscess in adults, especially in diabetic patients with an acute presentation, nonputrid sputum, multiple cavities, and failure to defervesce within 7 days after commencement of antimicrobial therapy. In an era of increasing numbers of *K. pneumoniae* infections and high proportions of penicillin- and clindamycin-resistant anaerobes and *S. milleri* group infections, a β-lactam/β-lactamase inhibitor or second- or third-generation cephalosporin plus clindamycin or metronidazole is recommended as empirical therapy for community-acquired cases of lung abscess. Use of clindamycin alone may no longer be appropriate.

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