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Different Bacteriology and Prognosis of Thoracic Empyemas Between Patients With Chronic and End-Stage Renal Disease*

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Background: **Bacterial infections are a well-documented complication in patients with chronic kidney disease (CKD) and end-stage renal disease (ESRD). However, there are no previous studies of the empyemas that can develop in these patients.**

Methods: **This retrospective study investigated the bacteriology and outcomes of empyema in stage 4 CKD (predialysis) and ESRD patients receiving long-term dialysis and treated in a tertiary university hospital from January 2001 to March 2006.**

Results: **Eighty-four stage 4 CKD patients and 40 ESRD patients had empyemas. Most empyemas (n = 77, 62%) were secondary to pneumonia. Empyema culture findings were positive in 102 patients (82%): 87 microorganism were isolated in pleural fluid from 67 stage 4 CKD patients, and 39 microorganisms were isolated in pleural fluid from 35 ESRD patients. Aerobic Gram-negative organisms (n = 58, 67%), especially *Klebsiella pneumoniae* (n = 20, 34%), were the predominant pathogens in stage 4 CKD patients; aerobic Gram-positive organisms (n = 21, 54%), especially *Staphylococcus aureus* (n = 14, 67%), were the main pathogens in ESRD patients. Compared to stage 4 CKD patients, ESRD patients had a significantly higher percentage of catheter infections (p = 0.002) and aerobic Gram-positive organism bacteremia (p = 0.001), as well as a lower aerobic Gram-negative organism infection rate (p < 0.001) and a lower infection-related mortality rate (p = 0.022).**

Conclusion: **Stage 4 CKD patients and ESRD patients with empyema have different causative pathogens and outcomes. In ESRD patients, the dialysis catheter or the dialysis process appear to alter the microbiological flora responsible for empyema. This finding has clinical implications that clinicians need to consider.** ***(CHEST 2007; 132:532–539)***

Key words: bacteriology; chronic kidney disease; empyema; end-stage renal disease

Abbreviations: CKD = chronic kidney disease; CMUH = China Medical University Hospital; CPPE = complicated parapneumonic effusion; ESRD = end-stage renal disease; GNB = Gram-negative bacilli; GPC = Gram-positive cocci; ORSA = oxacillin-resistant *Staphylococcus aureus*; PD = peritoneal dialysis; PE = pleural empyema

Chronic kidney disease (CKD), including end-stage renal disease (ESRD), is associated with an increased susceptibility to infection due to advanced age, immune dysfunction, underlying disease, and the dialysis procedure itself.[1] CKD and ESRD patients, *per se*, have a greater risk of pulmonary infections.[2,3] Among pulmonary infections, pleural empyema has a high mortality. It is usually a complication of pneumonia but may arise from hematog-

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enous seeding from an extrapulmonary focus.[4] However, little is known about the exact clinical characteristics and the bacteriology of empyemas in CKD patients, whether or not they are treated with maintenance dialysis.

To allow effective recommendations to be made and to improve the empirical therapeutic strategy for stage 4 CKD and ESRD patients with empyemas, we retrospectively reviewed the clinical features, causative pathogens, and outcomes of stage 4 CKD and ESRD patients receiving maintenance dialysis who had empyemas develop from January 2001 to March 2006 at a tertiary medical center. In this retrospective study, CKD patients were classified into predialysis (stage 4 CKD) and postdialysis (ESRD with long-term dialysis) groups to determine if the bacteriology and outcomes of empyema were different between these two groups.

Materials and Methods

Enrolled Patients

China Medical University Hospital (CMUH), a 1,677-bed facility, is a tertiary medical center located in central Taiwan. On average, our dialysis unit services 565 patients a month, including 340 patients receiving hemodialysis and 225 patients on peritoneal dialysis (PD). We retrospectively reviewed the computerized medical records of stage 4 CKD and ESRD patients receiving maintenance dialysis who had been admitted to CMUH with a diagnosis of thoracic empyema. From January 2001 through March 2006, 633 patients with empyemas were admitted to CMUH. Patients were excluded if the empyemas were traumatic, the patients had undergone repeated thoracenteses, or the chart was incomplete. Of these patients with empyema, 84 had stage 4 CKD and 40 had ESRD undergoing hemodialysis or PD for > 3 months.

Data Collection

The protocol was approved by the institutional review board of the CMUH. The following data were collected for each patient: age, gender, underlying disease, initial hemogram, biochemistry results, bacteria grown on pleural effusion cultures, treatment strategies, surgical interventions, and outcomes.

Definitions

CKD is the standardized nomenclature used for chronic diseases of the kidney. The National Kidney Foundation has defined the term *CKD* as evidence of kidney damage that persists for ≥ 3 months.[5] CKD severity is graded according to renal function, based on the estimates of the creatinine clearance calculated using the Cockcroft-Gault equation.[6] Stage 4 CKD is defined as an estimated glomerular filtration rate from 15 to 29 mL/min. ESRD (stage 5) is defined as an estimated glomerular filtration rate < 15 mL/min.

Based on Light's criteria and the literature,[7] simple complicated parapneumonic effusion (CPPE) was defined as a pleural fluid lactic dehydrogenase level $> 1{,}000$ IU/L, or a glucose level < 40 mg/dL, or a positive Gram stain or culture, with no fluid loculation and no frank pus. Complex complicated parapneumonic effusion was defined as pleural fluid that met the criteria of simple CPPE, but in addition the pleural fluid was loculated. Simple pleural empyema (PE) was defined as pleural fluid that contained frank pus in a single loculus. Complex PE was defined as multiloculated pleural fluid that contained frank pus. Hospital-acquired infection-related PE was defined as an infection that occurred > 48 h after admission with no evidence of infection on admission.[8] Pneumonia was defined clinically; febrile patients with purulent sputum, leukocytosis, and a new onset of pulmonary infiltrates on chest radiograph or CT were considered to have pneumonia. A catheter infection was defined as a positive culture finding with the same organism from a catheter segment and a peripheral blood sample.[9] A bacteriologic diagnosis based on the microbiological examination of the pleural fluid and other samples was also made. Bacteremia was defined as the isolation of a bacterial pathogen from two or more blood culture samples. The bacteria found in the pleural effusion were classified as follows: aerobic Gram-positive, aerobic Gram-negative, anaerobic, or polymicrobial bacteria. Polymicrobial infection was defined as the isolation of more than one strain of pathogen on the pleural effusion culture.

The administration of antimicrobial treatment was defined as inadequate if the antibiotics did not cover the infectious pathogens or, if due to resistance, the pathogens were not susceptible *in vitro* to the antibiotics. Patients in whom the infection was the cause of death were considered to have suffered infection-related mortality.

Statistical Analysis

The data were compiled and analyzed using commercial statistical software (SPSS for Windows, version 10.0; SPSS; Chicago, IL). All continuous variables are reported as mean $\pm$ SD and were compared using a two-tailed Student *t* test. Categorical variables are reported as the number of patients and percentage. Differences in categorical variables were examined using Fisher exact test. Multivariate stepwise logistic regression analysis was used to identify independently significant factors that predicted the percentage of Gram-positive and Gram-negative organisms and infection-related mortality. All tests of significance were two sided; $p \leq 0.05$ was considered statistically significant. Odds ratios and 95% confidence intervals were also calculated.

Results

Patient Characteristics, Underlying Disease, and Clinical Features

During the study period, empyemas or CPPEs developed in 84 stage 4 CKD patients and 40 ESRD patients receiving maintenance dialysis (88 men and 36 women). In the stage 4 CKD group, 11 patients had complex PE, 4 had simple PE, 60 had complex CPPE, and 9 had simple CPPE. In the ESRD group, 5 patients had complex PE, 2 had simple PE, 28 had complex CPPE, and 5 had simple CPPE. Overall, culture results were positive in 102 patients (82%), including 67 stage 4 CKD patients (66%) and 35 ESRD patients (34%). The average age of the 102 culture-positive PE or CPPE patients was 67 ± 14 years (range, 25 to 91 years). Most patients ($n = 93$, 91%) had a chronic underlying disease or associated

Table 1—*Clinical Characteristics of 102 Patients With Positive Culture Empyemas in CKD Stage 4 and ESRD With Hemodialysis or PD***

Patient Characteristics	All Patients (n = 102)	CKD Stage 4 (n = 67)	ESRD (n = 35)		p Value
			HD (n = 29)	PD (n = 6)	
Mean age, yr	66.8 ± 13.6	68.8 ± 13.6	62.6 ± 14.0	65.2 ± 8.2	NS
Male gender	71 (70)	42 (63)	15 (52)	4 (67)	NS
Body length, cm	158.4 ± 20.9	159.1 ± 17.1	155.2 ± 30.3	164.7 ± 5.7	NS
Body weight, kg	57.4 ± 11.3	57.8 ± 11.7	55.9 ± 11.3	58.7 ± 6.0	NS
Dialysis duration, mo		0	16.1 ± 26.4	26.7 ± 21.6	
Other underlying conditions					
Diabetes mellitus	43 (42)	26 (39)	12 (41)	5 (83)	NS
Malignancy	15 (15)	10 (15)	5 (17)	0 (0)	NS
Cerebrovascular disease	16 (16)	11 (16)	5 (17)	0 (0)	NS
Hypertensive cardiovascular disease	18 (18)	10 (15)	7 (24)	1 (17)	NS
Congestive heart failure	11 (11)	9 (13)	2 (7)	0 (0)	NS
COPD	7 (7)	5 (7)	1 (3)	1 (17)	NS
Previous pulmonary tuberculosis	3 (3)	2 (3)	1 (3)	0 (0)	NS
Liver cirrhosis	13 (13)	12 (18)	1 (3)	0 (0)	NS
Systemic lupus erythematous	2 (2)	0 (0)	2 (7)	0 (0)	NS
Peptic ulcerative disease	5 (5)	4 (6)	1 (3)	0 (0)	NS
Long-term steroid use	2 (2)	2 (3)	0 (0)	0 (0)	NS
Alcoholism	1 (1)	0 (0)	1 (3)	0 (0)	NS
No other underlying diseases	9 (9)	3 (4)	5 (17)	1 (17)	NS

*Data are presented as No. (%) or mean ± SD unless otherwise indicated. HD = hemodialysis; NS = not significant.

medical conditions; the most common concomitant conditions were diabetes mellitus (42%), hypertensive cardiovascular disease (18%), cerebrovascular disease (16%), and malignancy (15%). There was no significant difference in underlying diseases between the stage 4 CKD group and the ESRD group. Of the 35 culture-positive ESRD patients with empyema, 29 were receiving hemodialysis, and 6 were receiving PD. The mean duration of dialysis therapy was 18 ± 26 months (range, 3 to 96 months). Table 1 shows the clinical characteristics.

Table 2 shows the etiology of the pleural empyemas by group. In both groups, pneumonia was the predominant cause of empyema: 56 patients (67%) in the stage 4 CKD group, and 21 patients (52%) in the ESRD group. There were no statistically significant differences in the other causes of empyema between the groups, except that catheter infection was significantly more frequent in ESRD patients (25%) than in stage 4 CKD patients (6%).

Microbiology Results and Their Relationship to Clinical Characteristics

Overall, 87 organisms, including 81 aerobic bacteria, 4 anaerobic bacteria, and 2 tuberculosis bacteria, were isolated from 67 stage 4 CKD patients (Table 3). The most common bacteria were aerobic Gram-

Table 2—*Etiologies of PE Between the Groups of Chronic and ESRD***

Infection	All Patients (n = 124)	Patient Group		p Value
		CKD Stage 4 (n = 84)	ESRD (n = 40)	
Pneumonia	77 (62.2)	56 (66.7)	21 (52.5)	0.13
Infective endocarditis	1 (0.8)	1 (1.1)	0 (0)	0.49
Septic arthritis	4 (3.2)	3 (3.6)	1 (2.5)	0.75
Catheter infection	15 (12.1)	5 (6.0)	10 (25)	0.002
Urosepsis	2 (1.6)	1 (1.1)	1 (2.5)	0.59
Skin infection	1 (0.8)	0 (0)	1 (2.5)	0.15
Osteomyelitis	2 (1.6)	1 (1.1)	1 (2.5)	0.59
Liver abscess	2 (1.6)	2 (2.4)	0 (0)	0.33
Intra-abdominal abscess	5 (4.0)	4 (4.8)	1 (2.5)	0.55
Mediastinitis	2 (1.6)	2 (2.4)	0 (0)	0.33
Unknown	13 (10.5)	9 (10.8)	4 (10)	0.90

*Data are presented as No. (%).

Table 3—*Bacteriology of Positive-Culture Effusions in 67 CKD Stage 4 Patients and 35 ESRD Patients***

Isolates, by Class	CKD Stage 4		HD		PD		All Patients	
	CA	HA	CA	HA	CA	HA	CA	HA
Aerobic GPC	13	7	8	13	5	1	26	21
ORSA	0	3	2	7	0	0	2	10
Oxacillin-sensitive *S aureus*	1	2	3	2	0	0	4	4
Coagulase-negative staphylococcus	0	0	1	0	0	0	1	0
Streptococcus pneumoniae	3	0	2	1	1	0	6	1
S *viridans*	6	2	0	0	1	0	7	2
Streptococcus group D	1	0	0	0	0	0	1	0
Streptococcus group F	1	0	0	0	0	0	1	0
β-Streptococcus	1	0	0	0	0	0	1	0
Enterococcus spp	0	0	0	3	3	1	3	4
Aerobic GNB	33	25	6	8	1	1	40	34
K pneumoniae (ESBL)	0	2	0	0	0	0	0	2
K pneumoniae (non-ESBL)	15	3	4	1	0	0	19	4
E coli (ESBL)	1	1	0	1	0	0	1	2
E coli (non ESBL)	8	2	0	0	0	1	8	3
Pseudomonas aeruginosa	3	7	2	1	1	0	6	8
Burkholderia cepacia	1	3	0	1	0	0	1	4
Enterobacter cloacae	1	1	0	1	0	0	1	2
Enterobacter gergoviae	0	1	0	0	0	0	0	1
Proteus mirabilis	1	1	0	1	0	0	1	2
Acinetobacter baumannii	0	2	0	1	0	0	0	3
Acinetobacter lowffi	0	0	0	1	0	0	0	1
Salmonella enteritidis C2	2	0	0	0	0	0	2	0
Serratia marcescens	1	0	0	0	0	0	1	0
Comamonas testosteroni	0	1	0	0	0	0	0	1
Citrobacter freundii	0	1	0	0	0	0	0	1
Gram-positive bacilli	1	0	0	0	0	0	1	0
Nocardia	1	0	0	0	0	0	1	0
Anaerobes	5	1	1	3	0	0	6	4
Peptostreptococcus magnus	0	0	0	1	0	0	0	1
Bacteroides fragilis	2	0	0	2	0	0	2	2
Fusobacterium nucleatum	1	1	1	0	0	0	2	1
Prevotella denticola	1	0	0	0	0	0	1	0
Bifidobacterium spp	1	0	0	0	0	0	1	0
Tuberculosis	2	0	0	0	0	0	2	0

*Data are presented as No. CA = community acquired; HA = hospital acquired; HD = hemodialysis; ESBL = extended-spectrum β-lactamase.

negative organisms (n = 59, 68%). Of these, three of the most common Gram-negative pathogens accounted for 42 of the 87 positive-culture cases (48%): *Klebsiella pneumoniae* (n = 20, 23%), *Escherichia coli* (n = 12, 14%), and *Pseudomonas aeruginosa* (n = 10, 11%). The second-most-common organisms were aerobic Gram-positive organisms (23%), especially *Streptococcus viridans* (9%), which was the major Gram-positive empyema-causing organism.

In the 35 ESRD patients who had culture-positive empyemas, 47 organisms were recovered, including 43 aerobic bacteria and 4 anaerobic bacteria. The predominant bacteria were aerobic Gram-positive organisms (n = 27, 77%), of which *S aureus* (n = 14, 33%) and Enterococcus spp (n = 7, 16%) were responsible for 78% of the aerobic Gram-positive organism infections. The second-most-common organisms were aerobic Gram-negative organisms (n = 16, 34%); among these, *K pneumoniae* (n = 5, 12%) was the major causative organism.

Isolates from the 102 patients with positive-culture empyemas were further categorized as community acquired (n = 62) and hospital acquired (n = 40) [Fig 1, Table 3]. The causative microorganisms in the community-acquired empyema group differed from those in the hospital-acquired empyema group. In the community-acquired empyema group, *K pneumoniae* (n = 19, 31%) was the most common infecting organism; while in the hospital-acquired empyema group, oxacillin-resistant *Staphylococcus aureus* (ORSA) was predominant (n = 10, 25%). The causative microorganisms responsible for community-acquired and hospital-acquired infections differed between the stage 4 CKD and the ESRD patients. In the stage 4 CKD patients, aerobic Gram-negative pathogens were the main organisms responsible for both community-acquired and hos-

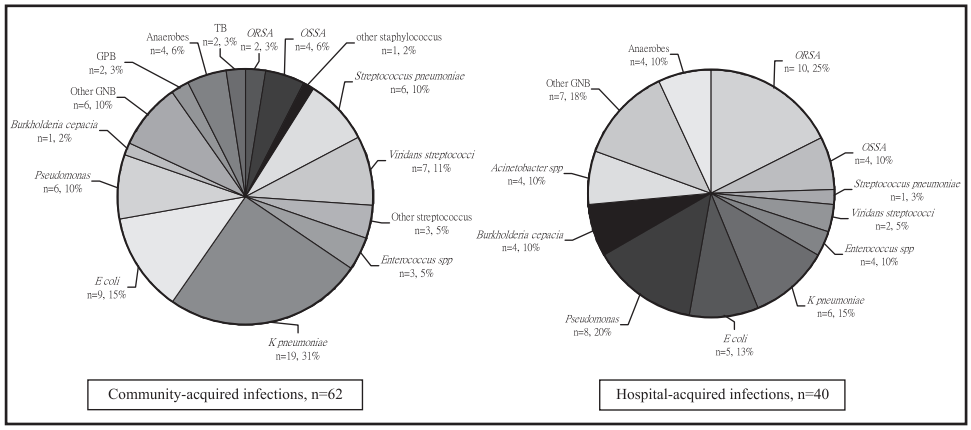

FIGURE 1. Bacteriology of 102 culture-positive effusions in patients with community-acquired and hospital-acquired infections. GPB = Gram-positive bacilli; TB = tuberculosis; OSSA = oxacillin-sensitive *S aureus*.

pital-acquired empyemas. The most common causative pathogen responsible for community-acquired empyema was *K pneumoniae* (n = 15, 45%); the most common causative pathogen in hospital-acquired empyema was *P aeruginosa* (n = 7, 28%). However, in ESRD patients, aerobic Gram-positive organisms were the main pathogens for both community-acquired and hospital-acquired empyemas. *S aureus* (n = 14, 67%) was the most common organism isolated. In the ESRD group receiving PD, eight bacterial pathogens were recovered from six patients; the predominant bacteria were also aerobic Gram-positive organisms (n = 6, 75%), especially Enterococcus (n = 4, 50%).

Laboratory data are shown by group in Table 4. There were no statistically significant differences between the stage 4 CKD and ESRD groups.

Treatments and Outcomes of Patients With Culture-Positive Empyemas

A total 110 patients (89%) received a pigtail catheter implant, and 14 patients (11%) required chest tube drainage as judged by the attending physician. Among these 110 patients with pigtail catheter drainage, 9 patients (8%) required fibrinolytic therapy because of a poor response to simple pigtail catheter drainage of CPPEs or empyemas. Of these patients receiving fibrinolytic therapy, seven patients were clinically improved and the other two

Table 4—*Comparison of Laboratory Values of Serum and Pleural Effusion Between CKD Stage 4 and ESRD Patients Receiving Hemodialysis and PD**

Patient Characteristics	All Patients (n = 102)	CKD Stage 4 (n = 67)	Hemodialysis (n = 29)	PD (n = 6)	p Value
Initial serum laboratory value					
Leukocyte count, $\times 10^3/\mu L$	15.0 ± 8.9	14.9 ± 9.9	15.8 ± 7.0	12.5 ± 3.6	NS
Hemoglobin, g/dL	10.2 ± 1.8	10.6 ± 1.9	9.4 ± 1.6	9.2 ± 1.3	NS
Albumin, mg/dL	1.9 ± 0.6	1.9 ± 0.5	2.0 ± 0.8	1.9 ± 0.5	NS
Positive blood culture results	32 (31)	17 (25)	14 (48)	1 (17)	NS
Side of empyema					
Right	59 (58)	36 (54)	20 (69)	3 (50)	NS
Left	43 (42)	31 (46)	9 (31)	3 (50)	NS
Initial empyema laboratory value					
Nucleated cells, μL	34.7 ± 48.6	36.9 ± 51.0	28.8 ± 44.8	37.6 ± 43.7	NS
Neutrophils, %	70.4 ± 30.4	70.8 ± 31.6	67.8 ± 30.3	76.8 ± 19.5	NS
Lactate dehydrogenase, IU/L	5811.6 ± 8929.0	5886.7 ± 8722.8	5768.3 ± 10174.7	5254.3 ± 6257.4	NS
Glucose, mg/dL	84.0 ± 91.5	83.7 ± 94.4	85.2 ± 83.1	83.0 ± 111.2	NS
Total protein, g/dL	3.3 ± 1.6	3.1 ± 1.7	3.9 ± 1.3	4.4 ± 2.0	NS
With central catheter	62 (60.8)	42 (62.7)	17 (58.6)	3 (50)	NS
With Hickmann catheter	10 (9.8)	0 (0)	10 (34.5)	0 (0)	

*Data are presented as No. (%) or mean ± SD. See Table 1 for expansion of abbreviation.

patients were treated using video-assisted thoracoscopic surgery due to poor control of the infection and/or poor drainage function. The successful rate of fibrinolytic therapy was 78%.

Thirty-two patients had positive blood culture findings. The incidence of aerobic Gram-positive coccus (n = 21, 66%) bacteremia was higher than that of aerobic Gram-negative bacilli (GNB) [n = 11, 34%; Table 5]. The rate of bacteremia was higher in the ESRD group (43%, 15 of 35 patients) than in the stage 4 CKD group (25%, 17 of 67 patients). Overall, the infection-related mortality rate was 43% (53 of 124 patients); 40 of 84 stage 4 CKD patients (48%) died, and 13 of 40 ESRD patients (33%) died. GNB infection (n = 32, 63%) was the predominant cause of infection-related mortality.

Discussion

To the best of our knowledge, this is the first study reported in the English-language literature that focused on empyemas in stage 4 CKD (predialysis) patients and ESRD patients receiving long-term dialysis. In stage 4 CKD patients with empyema, aerobic Gram-negative organisms were the predominant pathogens; *K pneumoniae* was the most frequently isolated sole pathogen. However, in ESRD patients receiving maintenance dialysis, aerobic Gram-positive organisms were the predominant pathogens. *S aureus* and Enterococcus spp were the most frequently isolated sole pathogens.

Over the past 20 years, aerobic Gram-positive organisms have been found to be the most common isolates in acute empyema,[10–12] particularly *S aureus* and *S pneumoniae*, which together accounted for approximately 70% of aerobic Gram-positive isolates. However, as recently reported,[13] there has been a significant increase in Gram-negative infection. In our study, aerobic Gram-negative bacteria were the major pathogens isolated from the empyemas of stage 4 CKD patients. Most stage 4 CKD patients (96%) with culture-positive empyema had underlying diseases; most patients were relatively immunocompromised hosts with diabetes mellitus (39%), malignancy (15%), or liver cirrhosis (18%). It is well known that immunocompromised patients are prone to pleural involvement with fungal or aerobic GNB infections.[12,14] The markedly high rate of Gram-negative bacterial infection in the empyemas of the stage 4 CKD patients may be associated with the high incidence of underlying disease and poor renal function. However, ESRD patients receiving long-term dialysis had a higher rate of bacteremia and aerobic Gram-positive empyemas despite a similar incidence of underlying disease and a similar frequency of central venous catheter implants (Table 1, 4). However, a higher incidence of Hickman insertion for maintenance dialysis was noted in ESRD patients. These factors may increase the frequency of these patients being exposed to potentially infectious factors during the normal course of dialysis therapy or being exposed to a catheter infection[15–17]; this may explain the bacteriologic findings in the empyemas of ESRD patients. In the present study, *S aureus* and Enterococcus spp, which

Table 5—*Incidence of Bacteremia, Pneumonia, Inadequate Antibiotic Treatment, and Mortality of Patients in CKD Stage 4 and ESRD Receiving Hemodialysis and PD**

Patient Characteristics	Bacteremia	Pulmonary Infiltration	Inadequate Antibiotic Use	Infection-Related Mortality
Stage 4 CKD group (n = 67)				
Aerobic GNB (n = 42)	9 (21)	25 (60)	16 (38)	28 (67)
Aerobic GPC (n = 16)	8 (50)	12 (75)	3 (19)	7 (44)
Aerobic Gram-positive bacilli (n = 1)	0 (0)	1 (100)	0 (0)	1 (100)
Anaerobes (n = 1)	0 (0)	0 (0)	0 (0)	0 (0)
Tuberculosis (n = 2)	0 (0)	2 (100)	2 (100)	0 (0)
Mixed (n = 5)	0 (0)	4 (80)	3 (100)	4 (80)
Hemodialysis group (n = 29)				
Aerobic GNB (n = 9)	2 (22)	6 (67)	3 (33)	4 (44)
Aerobic GPC (n = 16)	12 (75)	5 (31)	9 (56)	6 (38)
Anaerobes (n = 1)	0 (0)	1 (100)	0 (0)	0 (0)
Mixed (n = 3)	0 (0)	3 (100)	1 (33)	1 (33)
PD group (n = 6)				
Aerobic GNB (n = 0)	0 (0)	0 (0)	0 (0)	0 (0)
Aerobic GPC (n = 4)	1 (25)	2 (50)	2 (50)	1 (25)
Anaerobes (n = 0)	0 (0)	0 (0)	0 (0)	0 (0)
Mixed (n = 2)	0 (0)	2 (100)	2 (50)	1 (50)

*Data are presented as No. (%).

are normal skin and intestinal flora, were the most frequently isolated sole pathogens in ESRD patients receiving hemodialysis and PD.

Compared to the recently published Multicenter Intrapleural Sepsis Trial 1,[18,19] there were clear differences between the general population and CKD patients (with or without dialysis) in the pathogens isolated in those with empyemas (Fig 1). In the present study, aerobic Gram-negative organisms rather than aerobic Gram-positive organisms, and particularly *K pneumoniae* rather than Streptococcus spp, were the main causative microorganisms of empyema in stage 4 CKD patients. Theoretically, in relatively immunocompromised hosts, renal functional impairment or underlying disease may favor these pathogens. However, among hospital-acquired infections, ORSA was still the most common pathogen, not only in the general population, but also in patients with chronic kidney disease. These results may imply that, when treating patients with renal functional impairment, different antibiotics should be used empirically in hospital- and community-acquired empyemas.

In our study, 61% of stage 4 CKD patients and 67% of ESRD patients receiving hemodialysis had pneumonia at the time that an aerobic GNB empyema was diagnosed (Table 4). It is thought that the infectious process occurring in the pleural cavity may be due to bacteria from the lung parenchyma secondarily invading the pleural space. A similar situation was also noted in the stage 4 CKD group, in which empyema was caused by aerobic Gram-positive cocci (GPC). However, only 31% of hemodialysis patients with aerobic GPC empyemas had pneumonia; however, 75% of hemodialysis patients had bacteremia. Therefore, the majority of GPC empyemas were related to the presence of bacteremia in dialysis patients due to hematogenous seeding of an extrapulmonary focus, likely related to dialysis catheter implants and/or the dialysis process.

A higher mortality rate was noted among stage 4 CKD patients than among ESRD patients. This may be due to the fact that GNB were the predominant pathogens in the stage 4 CKD 4 group; GNB are more toxic than GPC, which were the major pathogen in the ESRD group. Hence, patients with *S aureus* empyema receiving long-term hemodialysis have a favorable prognosis, particularly compared to CKD patients not receiving dialysis.

In our series, the successful rate of fibrinolytic therapy in these patients with poor catheter drainage was 78% (seven of nine patients). Our finding confirms that fibrinolytic therapy is effective in the treatment of poor catheter drainage in patients with CPPEs or empyemas, which was comparable to these previous studies.[20,21]

Previous studies[22–24] noted an important association between inadequate antimicrobial treatment for bacteremia and hospital mortality. In the present study, among the stage 4 CKD group with aerobic Gram-negative empyema, 16 patients initially received inadequate antimicrobial treatment, and their mortality rate was 81% (13 of 16 patients); the other 27 patients initially received adequate antimicrobial treatment, and their mortality rate was 56% (15 of 27 patients). Among the stage 4 CKD group with aerobic Gram-positive empyema, 2 patients initially received inadequate antimicrobial treatment (mortality rate, 50%; 1 of 2 patients); the other 14 patients initially received adequate antimicrobial treatment (mortality rate, 42%; 6 of 14 patients). Similar results were observed in the ESRD patients receiving hemodialysis. In the aerobic Gram-negative group, three patients initially received inadequate antimicrobial treatment (mortality rate, 67%; two of three patients); the other six patients initially received adequate antimicrobial treatment (mortality rate, 33%; two of six patients). In the aerobic Gram-positive group, nine patients initially received inadequate antimicrobial treatment (mortality rate, 33%; three patients); the other seven patients initially received adequate antimicrobial treatment (mortality rate, 43%; three of seven patients). Due to the lower toxicity of Gram-positive organisms, inadequate antimicrobial treatment did not contribute to hospital mortality. However, inadequate antimicrobial treatment was an important factor in patients with aerobic Gram-negative empyemas, both in the stage 4 CKD group and the ESRD group.

The present study had several limitations. First, all of the patients were recruited from our hospital.The prevalence of etiologies may differ in other geographic regions. Second, this was a retrospective study. Also, the sample size of the ESRD group receiving maintenance PD therapy was small, even though an average of 225 ESRD patients per month have been receiving PD in our hospital in recent years. A large prospective, randomized trial is required to confirm our results with respect to the ESRD group receiving maintenance PD therapy who have empyema develop.

In conclusion, empyema has a high mortality in stage 4 CKD and ESRD patients. The causative pathogens and outcomes of empyemas differ between stage 4 CKD patients and ESRD patients; it appears that the dialysis catheter or the dialysis process itself are responsible for the differences. Clinicians treating patients with renal functional impairment who have empyema develop must take into consideration the dialysis status when empirically choosing antibiotics while awaiting culture re-

sults. Thus, these findings are clinically applicable in the treatment of patients with chronic renal failure and empyema.

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Different Bacteriology and Prognosis of Thoracic Empyemas Between Patients With Chronic and End-Stage Renal Disease*

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