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Clinical features, risk factors, and antimicrobial resistance of pseudomonas putida isolates

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Abstract

Pseudomonas putida rarely results in infection, primarily in patients undergoing invasive procedures or immunocompromised hosts. We aimed to investigate the characteristics of *Pseudomonas putida* infections. This is a retrospectively designed cross-sectional observational study. We retrospectively scanned the data from our hospital for the 10 years before February 15, 2022. The patients with *Pseudomonas putida* growth in the microbiological cultures and with antibiotic susceptibility tests were included in the study. We recorded culture isolates types, age, gender, comorbidities, immunosuppressive factors, symptoms, invasive medical procedures, length of hospital stay, and radiological findings. The mean age of the patients was 66.2 ± 14.5 years, and the male patients predominated (76.3%, n = 58/76). There was growth in bronchial lavage in 33 patients, sputum in 28, pleural effusion fluid in 12, and tracheal aspirate in 3 patients. The rate of antibiotic-resistant strains was 56.6% (n = 43). All strains were sensitive to colistin (100%), and carbapenem, amikacin, and gentamicin sensitivity rates were high. We observed that the risk of antibiotic resistance increased 4.29 times in the patients in the intensive care unit (CI:1.27–14.47, P = .01). The patients with Diabetes Mellitus had a higher risk (OR 4.33, CI:1.11–16.77, P = .03), and in cancer cases, the risk was 3.31 times higher (CI:1.06–10.32, P = .03). The risk of *Pseudomonas putida* infection should be considered, particularly in patients with comorbid disorders causing immunosuppression, including Diabetes Mellitus and Cancer.

Abbreviations: COPD = chronic obstructive pulmonary disease, DM = diabetes mellitus, EUCAST = the European committee on antimicrobial susceptibility testing, ICU = the intensive care unit, LC = lung cancer, NSCLC = non-small cell lung cancer, *P. Putida* = Pseudomonas putida, T-CT = thorax computed tomography.

Keywords: antibiotic resistance, immunosuppression, invasive procedures, Pseudomonas putida

1. Introduction

Pseudomonas putida (*P. putida*) belongs to the fluorescent group of opportunistic Pseudomonas species. It is commonly found on inanimate surfaces in hospitals and humid places due to its strong tolerance to harsh living conditions and causes nosocomial infections.[1,2]

It has been reported that the pathogenicity of *P. putida* is less compared to other Pseudomonas species, and it is sensitive to many antimicrobial agents. Therefore, *P. putida* infections are rarely seen in clinics.[3]

In recent years, the isolation rate of re *P. putida* has increased, and the emergence of multi-drug resistant and even extensively drug-resistant strains has been a cause for concern. Although this microbial agent causes infections in cancer and immuno-suppressed patients and is less virulent than *Pseudomonas aeruginosa*, fatal diseases have been reported.[4,5]

P. putida infections used to be known to have a good prognosis. However, recent studies reported a high mortality rate (40%), particularly in patients with comorbid conditions,[5,6] attracting the attention of clinicians.[7]

Our study investigated the clinical features, risk factors, and antimicrobial resistance rates in patients with positive *P. putida* cultures.

2. Materials and Methods

This study is a retrospectively designed cross-sectional observational study. We retrospectively scanned the data of our hospital for the 10 years before February 15, 2022, and 76 patients (58 inpatients, 18 outpatients) with *P. putida* growth in the microbiological cultures and with antibiotic susceptibility tests were included in the study. Four patients with missing information in

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Highlights

- This study was performed in a Chest and Respiratory Diseases Hospital and on the bacterial culture-positive cases of *P. putida*. All samples were pulmonary in origin. To our knowledge, this study contains the largest number of *P. putida* cases in the literature.
- This study reports the antibiotic resistance profile, risk factors, symptoms, and pulmonary radiological features of pulmonary *P. putida* cases.

their files were excluded. Resistance to any antibiotic was considered antibiotic resistance.

We recorded localizations of bacterial isolation (sputum, bronchial lavage, pleural effusion, tracheal aspirate), age, gender, comorbidities, factors causing immunosuppression (cancer type in patients with lung cancer [LC], chemoradiotherapy), symptoms, invasive medical procedures (catheter, pleural drainage, tube thoracostomy, intubation), length of hospital stay, microbiology culture results, antibiotic resistance, and the radiological findings on thorax computed tomography (T-CT) including bronchial obstruction, bronchiectasis, pleural effusion, and parenchyma findings.

2.1. Study group

We retrospectively scanned the data from our hospital for the 10 years before February 15, 2022. The patients with *P. putida* growth in the microbiological cultures and with antibiotic susceptibility tests were included in the study.

2.2. Bacterial identification and antimicrobial susceptibility test

Bacterial culture and antibiogram procedures were studied according to "the European committee on antimicrobial susceptibility testing (EUCAST)" Clinical breakpoints-bacteria (v 12.0) standards. We used the BD Phoenix™ M50 automated identification and susceptibility tester to identify and antibiogram *P. putida* strains. In addition to the BD Phoenix ™ M50 device, we used conventional methods such as disc diffusion and gradient tests for sensitivity tests. Diagnostics MIC-COL (Diagnostics I.n.c., Galanta, Slovakia) microtube dilution method was used for colistin within the framework of EUCAST standards. *Pseudomonas aeruginosa* ATCC 27853 was used as a reference strain for quality control. Inhibition zone diameters and MIC values for the Gradient test and Microtube dilution test were measured and interpreted according to EUCAST standards. We showed the final results as susceptible (S), high dose susceptible (I), and resistant (R). The antimicrobial agents involved were: colistin, meropenem, ciprofloxacin, gentamicin, amikacin, imipenem, ceftazidime, aztreonam, levofloxacin, piperacillin/tasomeric acid – sensitivity disk provided by OX-OID Company.

2.3. Statistical analysis

We analyzed the data of the patients with statistical package for the social sciences (SPSS, IBM Corp., Armonk, New York) for Windows 23.0 software. Mann-Whitney U test was used to analyze the descriptive statistical parameters (mean, standard deviation) that did not conform to a normal distribution. We performed binary logistic regression analysis to determine the effects of demographic data, computed tomography findings, and the presence of comorbid disorders on the likelihood of having antibiotic-resistant *P. putida* isolate. We evaluated

results at a 95% confidence interval and a significance level of $P < .05$.

2.4. Limitations

This study had some limitations. Since our hospital where this cross-sectional study was conducted is a Chest and Respiratory Diseases Hospital, the number of patients diagnosed with chronic obstructive pulmonary disease (COPD) was high. The isolates were only acquired from the respiratory tract, which might have affected the symptom diversity. We may obtain different results in a hospital where general patients are hospitalized. In patients with lung disorders, we may relate the findings to the primary disease, which should be kept in mind. Data on antimicrobial treatments administered before culture results and changes in the treatment after obtaining the culture results were available in a limited number of cases. We did not include the management of the patients in the study. As this is a retrospective study, electronic data records were adhered to.

3. Results

3.1. Sample source and distribution of p. Putida

The mean age of 76 patients included in the study was 66.2 ± 14.5 years. Male patients were predominant (76.3%, n = 58/76). The length of hospital stay was 12.6 ± 10.2 days (76.3%, n = 58). The distribution of samples to clinics was determined as 44.7% (n = 34) from the chest diseases clinic, 26.3% (n = 20) from the intensive care unit (ICU), and 28.9% (n = 22) from the thoracic surgery clinic. The bacterial growth was observed in the bronchial lavage in 43.4% (n = 33), in sputum in 36.8% (n = 28), in pleural effusion in 15.8% (n = 12), and in tracheal aspirate in 3.9% (n = 3) of the patients.

3.2. Risk factors

Nineteen patients had a history of invasive procedures, including tube drainage (n = 12), tracheostomy (n = 4), and intubation (n = 3). The most common comorbidities were COPD in 53.9% (n = 41), hypertension in 42.1% (n = 32), and cardiovascular disorders in 39.5% (n = 27) of the patients. Non-small cell lung cancer (NSCLC) was the most frequent LC (n = 21), and squamous cell cancer was the most frequent NSCLC (n = 8/21) (See Table 1).

3.3. Clinical and radiological findings

As the symptoms were considered, there was dyspnea in 68.4% (n = 52), cough in 51.3% (n = 39), and fever in 14.5% (n = 11) of the patients. Since our study was conducted in a Chest and Respiratory Diseases Hospital, it was inevitable that respiratory symptoms were predominant in the patients (See Fig. 1).

T-CT was obtained in 93.4% (n = 71/76) of the patients. The most common radiological findings were consolidation in 40.7% (n = 31), pleural effusion in 25.0% (n = 19) and central bronchiectasis in 18.4% (n = 14) of the cases.

All-cause mortality within the 30 days after the positive microbiological culture was seen in 11 patients (14.4%). Nine of them were over 65 years, 7 of them had coinfection with other microorganisms and 7 of them had invasive procedures before *P. putida* growth (See Table 1).

3.4. The prevalence of p. Putida resistance and polymicrobial growth

There were resistant strains in 56.6% (n = 43) of the patients. We detected single antibiotic resistance in 9.2% (n = 7);

The demographic characteristics of patients [n = 76 (%)].

Demographic data		Computed Tomography Findings	71 (93.4)
Age (yrs)	66.2 ± 14.5	Consolidation	31 (40.7)
Gender (M)	58 (76.3)	Pleural effusion	19 (25.0)
Smoking	26 (34.2)	Central bronchiectasis	14 (18.4)
Hospitalized patients	58 (76.3)	Mass lesion	12 (14.4)
Mean hospital stay	12.6 ± 10.2	Ground glass	7 (9.2)
The clinic that requested the culture		Emphysema	7 (9.2)
Chest Diseases Clinic	34 (44.7)	Cavitation	6 (7.8)
Thoracic Surgery Clinic	22 (28.9)	Bronchial obstruction	6 (7.8)
Intensive Care Unit	20 (26.3)	Pneumothorax	2 (2.6)
Site of sampling		**Comorbidity**	**63 (82.9)**
Bronchial lavage	33 (43.4)	COPD	41 (53.9)
Sputum	28 (36.8)	Hypertension	32 (42.1)
Pleural effusion	12 (15.8)	Cardiovascular disorder	27 (39.5)
Tracheal aspirate	3 (3.9)	Lung cancer	21 (27.6)
No symptoms	**8 (10.5)**	Squamous cell	8 (10.5)
Presence of invasive Procedures	**19 (25)**	Adenocancer	7 (9.2)
Tube drain	12 (15.7)	Small Cell	4 (5.3)
Tracheostomy	4 (5.2)	Other	2 (2.6)
Intubation	3 (3.9)	Diabetes mellitus	16 (21.1)
Polymicrobial growth	**26 (34.2)**	Tuberculosis History	8 (10.5)
One co-pathogen	23 (30.3)	Cerebrovascular disease	5 (6.6)
Two co-pathogens	3 (3.9)	Chronic kidney failure	3 (3.9)
Single drug resistance	**7 (9.2)**	**Mortality within 30 d**	**11 (14.4)**
Multidrug resistance	**36 (47.4)**	Geriatric patient (>65 yrs)	9 (11.8)
		Coinfection	7 (9.2)
		Invasive procedure	7 (9.2)
		Multidrug resistance	4 (5.3)
		Lung cancer	1 (1.3)

COPD = chronic obstructive pulmonary disease.

multi-antibiotic resistance was seen in 43.4% (n = 33) of the patients. One co-pathogen growth was seen in 30.3% (n:23), and 2 or more co-pathogen growth was seen in 3.9% (n = 3).

While all *P. putida* isolates were sensitive to colistin, their sensitivity to gentamicin, amikacin, and meropenem was high. In the resistant group, resistance rates were high for aztreonam (62.5%), levofloxacin, and ciprofloxacin (46.1%) (See Table 2).

Binary logistic regression analysis was employed to examine the correlation of the findings with antibiotic resistance. It was determined that age (OR 1.00, Cl: 0.97–1.03, P = .92), gender (OR 1.74, Cl: 0.57–5.27, P = .32), and being symptomatic (OR 1.34, Cl: 0.31-5.83, P = .69) did not increased the risk for antibiotic resistance.

The risk of antibiotic resistance was 3.52 (Cl:1.15–10.76, P = .02) times higher in hospitalized patients than in outpatients, and the risk was 4.29 (CI:1.27–14.47, P = .01) times higher in the patients in ICU compared to the 1s who were not in ICU.

Invasive procedures (OR 0.60, Cl:0.21–1.73, P = .35) or smoking history (OR 0.84, Cl:0.32–2.19, P = .72) did not significantly increase the risk for resistance.

When the radiological findings were examined, it was determined that 39 patients had T-CTs in the antibiotic resistance group. Central bronchiectasis was strongly correlated with antibiotic resistance (OR 6.66, Cl:1.36–32.51, P = .01). We found that the presence of consolidation was associated or correlated to resistant strain 2.84 times (Cl:1.06–7.58, P = .03). Although the presence of a cavitary lesion seemed to be associated or correlated to resistant strain 4.55 times but the result was not statistically significant (Cl: 0.50–41.20, P = .17). The presence of emphysema (OR 0.29, Cl: 0.06–1.62, P = .15) and bronchial obstruction (OR 0.80, Cl: 0.15–4.29, P = .80) seemed to be negatively correlated. However, the result was not statistically significant.

There were comorbid disorders in 33 patients in the risk group for antibiotic resistance. COPD, the most common comorbid condition in the patient group, increased the risk 2.87 times (Cl:1.12–7.34, P = .03). It was determined that the comorbid disorder which increased the risk for antibiotic resistance the most was diabetes mellitus (DM) (OR 4.33, Cl:1.11–16.77, P = .03). The risk was 3.31 times higher in patients with LC (Cl:1.06–10.32, P = .03). Other comorbidities were not correlated with an increased risk for antibiotic resistance (See Table 3).
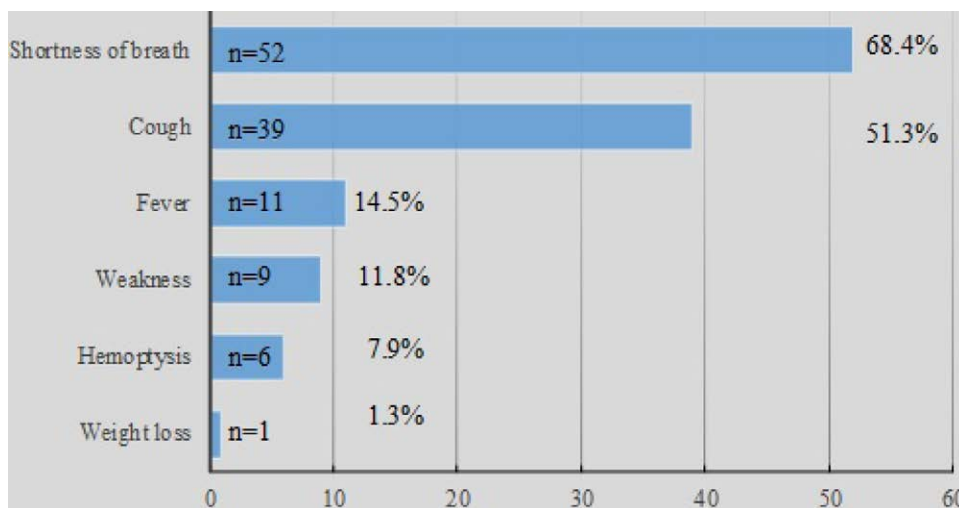

Figure 1. Distribution of symptoms.

Table 2

Antibiotic resistance of P. Putida isolates.

Antibiotic	n	Sensitive n = 33 (43.4%)	Resistant n = 43 (56.6%)
Colistin	76	76 (100)	-
Meropenem	76	63 (82.9)	13 (17.1)
Amikacin	76	73 (96.1)	3 (3.9)
Ceftazidime	76	62 (81.6)	14 (18.4)
Piperacillin-Tazobactam	76	50 (65.3)	26 (34.2)
Gentamicin	51	45 (88.2)	6 (11.8)
İmipenem	50	43 (86)	7 (14)
Levofloxacin	76	41 (53.9)	35 (46.1)
Ciprofloxacin	76	41 (53.9)	35 (46.1)
Aztreonam	24	9 (35.5)	15 (62.5)

(%) row percentage

Table 3

Evaluation of the risk for antibiotic resistance.

	Resistant group	OR (95% CI) for antibiotic-resistant	p
Demographic data	n = 43		
Age	66.4 ± 14.6	1.00 (0.97–1.03)	.92
Gender (F)	12 (27.9)	1.74 (0.57–5.27)	.32
Smoking	14 (32.6)	0.84 (0.32–2.19)	.72
Hospitalized patients	37 (86.0)	**3.52 (1.15–10.76)**	**.02***
Hospitalization in the intensive care unit	16 (37.2)	**4.29 (1.27–14.47)**	**.01***
Presence of symptoms	39 (90.7)	1.34 (0.31–5.83)	.69
Invasive procedures	9 (20.9)	0.60 (0.21–1.73)	.35
Computed Tomography Findings			
Consolidation	22 (56.4)	**2.84 (1.06–7.58)**	**.03***
Pleural effusion	11 (28.2)	1.17 (0.40–3.40)	.76
Central bronchiectasis	12 (30.7)	**6.66 (1.36–32.51)**	**.01***
Mass lesion	7 (17.9)	1.18 (0.33–4.15)	.79
Ground glass appearance	6 (15.3)	2.07 (0.21–19.67)	.52
Emphysema	2 (5.1)	0.29 (0.06–1.62)	.15
Cavitary lesion	5 (12.8)	4.55 (0.50–41.20)	.17
Bronchial obstruction	3 (7.6)	0.80 (0.15–4.29)	.80
Presence of comorbid disorder	n = 33		
COPD	28 (84.8)	**2.87 (1.12–7.34)**	**.03***
Hypertension	18 (54.5)	0.97 (0.39–2.44)	.96
Cardiovascular disease	14 (42.4)	1.50 (0.54–4.18)	.43
Lung cancer	16 (48.4)	**3.31 (1.06–10.32)**	**.03***
Diabetes mellitus	13 (39.3)	**4.33 (1.11–16.77)**	**.03***
Tuberculosis History	6 (18.2)	2.51 (0.47–13.35)	.27
Cerebrovascular disease	2 (6.1)	0.48 (0.07–3.10)	.44
Chronic kidney failure	1 (3)	0.36 (0.03–4.25)	.42

(%) = column percentages, COPD = chronic obstructive pulmonary disease, OR = 1 implies the probability of antibiotic resistance.

*P value = 0.05 significant.

4. Discussion

In the 1980s, P. putida bacteremia was first reported in cancer patients[8,9] and later in patients with catheter-related bloodstream infections, pneumonia, acute cholecystitis, cholangitis, skin, and soft tissue infections[6,10,11]

P. putida strains are rarely isolated from clinical specimens, suggesting that they survive in a hospital setting and sometimes cause nosocomial infections in seriously ill or immunocompromised patients.[12–14]

In multidisciplinary studies, P. putida was isolated most frequently from the patients hospitalized in surgery clinics, including neurosurgery (15.6%), organ transplantation (9.4%), orthopedics (9.4%), as well as chest diseases clinic (9.4%).[7,14]

Our study was performed in the clinics of a Chest and Respiratory Diseases Hospital, and 44.7% of P. putida growth was observed in the samples sent from the chest diseases clinic, 28.9% were grown from the samples sent from the thoracic surgery clinic, and 26.3% were grown in the samples sent from ICU. In binary logistic regression analysis, the risk of antibiotic resistance was 4.29 times higher in the intensive care unit patients (Cl:1.27–14.47, P = .01). In addition, it was 3.52 times higher in hospitalized patients than in outpatients (Cl:1.15–10.76, P = .02).

Urine and blood are in the first place for culture-positive P. putida samples in general hospitals, and P. putida growth rate in sputum was reported as 12.5%.[7,15] Our study was performed only with respiratory tract samples, and P. putida growth in the cultures was most frequent in bronchial lavage (43.4%) and sputum (36.8%) and the least frequent in tracheal aspirate samples (3.9%).

In the studies, the mortality reates were inconsistent. One of the study reported that the mortality rate was 7.9% (1/28)[6] and another study reported that the case fatality rate was 29% (12/41).[15] Our cohort had all-cause mortality within the 30 days after the positive microbiological culture was 14.4% (11/76).

In studies conducted in multidisciplinary centers, invasive surgical procedures, drainage tubes, urinary catheters, and femoral venous catheters have been reported in the 1st place in parallel with the fact that surgical services are in the first place in terms of samples positive for P. putida growth.[7] In another study, they reported that P. putida was colonized in the tissues of immunocompromised patients with bile drainage tubes.[6] In our study, the most common invasive procedure was tube drainage (15.7%), which is consistent with the literature. Despite the general knowledge that the presence of an invasive procedure increases the risk of P. putida infection, our study found that the presence of an invasive procedure did not significantly increase the risk of antibiotic resistance (OR 0.60, Cl:0.21–1.73, P = .35).

In addition to the study which reported solid tumors, hematological malignancy, and immunosuppressive conditions as the most common underlying disorders in patients with P. putida growth,[5] another study reported that 85.7% of 28 cases with P. putida growth were immunosuppressed, and opportunistic P. putida infections were observed mainly in the patients with immunosuppression, low physical performance, and comorbid disorders.[7,9,16,17]

In our study on patients with pulmonary disorders, COPD may be regarded as a disorder causing poor physical performance, which was present in 53.9% of the patients. In the antibiotic resistance risk analysis, we found that COPD increased the risk 2.87 times (Cl:1.12–7.34, P = .03). In the immunosuppressed group, the rate of lung cancer patients receiving chemoradiotherapy was 27.6%. The most common lung cancer subtype was NSCLC (Squamous cell, 10.5%) and the risk for antibiotic resistance was 3.31 times higher in cancer patients (CI:1.06–10.32, P = .03).

The most common extrapulmonary disorders were hypertension (42.1%), cardiovascular disorders (39.5%), and DM (21.1%). In evaluating antibiotic resistance risk with binary logistic regression analysis, DM was determined as the comorbid disorder that increased the risk the most (OR 4.33, Cl:1.11–16.77, P = .03).

In this study which we conducted in a Chest and Respiratory Diseases Hospital and only with respiratory tract samples, the most common T-CT findings were consolidation (40.7%), pleural effusion (25.0%), central bronchiectasis (18.4%), and more rarely mass, ground glass appearance, emphysema, cavitary lesion, bronchial obstruction, and pneumothorax. T-CT was performed on 39 patients in the antibiotic-resistant group. We found that central bronchiectasis strongly correlated with antibiotic resistance (OR 6.66, Cl:1.36–32.51, P = .01), while pneumonic consolidation increased the risk 2.84 times (CI:1.06–7.58, P = .03). Although the presence of a cavitary lesion seemed to increase the risk 4.55 times (Cl: 0.50–41.20, P = .17), the result was not statistically significant.

Fever was reported as the most common symptom in the previous studies that included multidisciplinary clinical data.[7] In our study, the most common symptom was dyspnea (68.4%) (cough 51.3%, fever 14.5%), but it was observed that being symptomatic or not was not correlated with the risk of antibiotic resistance (OR 1.34, CI: 0.31–5.83, P = .69).

In our Chest and Respiratory Diseases Hospital, it was inevitable that respiratory symptoms were predominant in the patients, both comorbid disorders and the factors causing immunosuppression were pulmonary in origin, and our study was conducted only with respiratory tract samples.

4.1. Antibiotic resistance in p. Putida hospital isolates

P. putida has generally been considered low virulence and has little clinical significance. In the literature, it has been reported that the prognosis of *P. putida* bacteremia is good, with an improvement rate of 93%.[6,18]

In the earlier studies, Fass et al found that clinical isolates of *P. putida* were susceptible to various antibiotics (100% sensitivity to ciprofloxacin and tobramycin, 87% sensitivity to imipenem and piperacillin/tazobactam).[19] Another recent study reported sensitivity to ciprofloxacin (54.5%), amikacin (86.4%), and gentamicin (56.8%).[7]

Our study found the sensitivity rates for tobramycin, ciprofloxacin, imipenem, piperacillin/tazobactam, amikacin, and gentamicin to 96.0%, 53.9%, 86.0%, 65.3%, 96.1%, and 88.2%, respectively. The low sensitivity to ciprofloxacin may be attributed to the widespread use of this agent over the years. We conducted this study with data from a tertiary medical center, and the frequent use of antibiotics in hospitalized patients may be the reason for the low sensitivity to piperacillin/tazobactam. Likewise, our study's lowest preference for gentamicin in our chest diseases hospital might have resulted in high sensitivity to gentamicin. In addition, Sader et al reported amikacin sensitivity as 79.8%.[20] Our amikacin sensitivity rate was similar to the literature.

Studies conducted in the following years have reported an increasing number of carbapenem-resistant *P. putida* isolates.[21,22] Within the scope of the Korean nationwide surveillance of antimicrobial resistance, 8 (67%) isolates were identified as *P. putida* in the analysis of carbapenem-resistant (12 imipenem-resistant isolates) of Pseudomonas species other than *P. aeruginosa*.[23]

In a study conducted with 18 *P. putida* isolates, 22% were resistant to imipenem, and 28% were resistant to meropenem. The same study compared carbapenem resistance rates with *P. aeruginosa* and found no significant difference. The aztreonam resistance rate of *P. putida* (72%) was higher than *P. aeruginosa*. With these findings, it was reported that multi-drug and carbapenem resistance is common not only in *P. aeruginosa* but also in *P. putida* isolates.[5] In another study, it was sensitive to aztreonam (88.6%), imipenem (62.8%), and meropenem (45.5%).[7]

We found the aztreonam resistance rate (62.5%) to be compatible with some studies in the literature and inconsistent with others. We found carbapenem resistance rates to be lower than other studies in the literature (meropenem 17.1%, imipenem

14.0%). These low resistance rates may be due to the controlled use of carbapenems or their usage as the last step in our tertiary medical center.

In our study, the prevalence of antibiotic resistance was 9.2% for a single antibiotic and 43.4% for more-than-1 antibiotic multi-drug resistant, which was lower than the literature data (75%).[7] On the other hand, the polymicrobial growth rate was 3.9% for 2 or more pathogens and 30.3% for 1 pathogen, and lower than the literature data (>2 pathogens 18.8%, 1 pathogen 59.4%).[7]

5. Conclusion

High rates of antibiotic resistance may be observed in patients with lung cancer, DM as comorbidity, hospitalized in the ICU, and patients with radiological bronchiectasis. The susceptibility rates of *P. putida* for imipenem, meropenem, gentamicin, and amikacin are still high. These agents may be used as the first choice antibiotics in *P. putida* infections for successful treatment of the condition.

Author contributions

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