

Research article

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Antibiotic Resistance of *Pseudomonas aeruginosa* at Children's Hospital 2 from September 2023 to May 2024

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Abstract

Introduction: The antibiotic resistance of Gram-negative bacteria, particularly *Pseudomonas aeruginosa*, is becoming increasingly severe. Understanding the biological characteristics of *P. aeruginosa* plays a crucial role in infection control and optimizing antibiotic use in hospitals.

Objective: To evaluate the antibiotic resistance pattern of *P. aeruginosa* at Children's Hospital 2 from September 1, 2023, to May 31, 2024.

Subjects and Methods: This retrospective cross-sectional study was conducted on pediatric patients who underwent culture, isolation, and antibiotic susceptibility testing of *P. aeruginosa* at the Microbiology Department of Children's Hospital 2 during the study period. Antibiotic susceptibility was assessed following the Clinical and Laboratory Standards Institute (CLSI) guidelines.

Results: During the study period, 392 *P. aeruginosa* isolates were identified, predominantly from children aged 0 to 11 months (52.3%), the Respiratory Department (24.0%), and lower respiratory tract specimens (82.5%). Regarding antibiotic resistance, the highest resistance rates were observed for Imipenem (37.8%), Ciprofloxacin (34.9%), and Meropenem (31.6%). Lower resistance rates were found for Ceftazidime-Avibactam (19.6%), Piperacillin-Tazobactam (25.8%), and Colistin (4.1%). Samples from children under 11 months, patients in the Intensive Care Unit (ICU), and lower respiratory tract specimens exhibited higher resistance rates.

Conclusion: The antibiotic resistance of *P. aeruginosa*, particularly in children under 11 months of age and from lower respiratory tract specimens, poses significant challenges in clinical treatment. The high resistance rates to Carbapenem antibiotics (such as Imipenem and Meropenem), Ceftazidime, Ciprofloxacin, and Gentamicin underscore the urgent need to optimize antibiotic use and strengthen infection control measures. Preserving the efficacy of last-resort antibiotics, including Colistin, Amikacin, and Ceftazidime-Avibactam, is crucial. Additionally, comprehensive genomic and phenotypic studies on resistance mechanisms and the development of novel therapeutic approaches are essential for enhancing infection management and antimicrobial stewardship in the future.

Keywords: Children's Hospital 2, *P. aeruginosa*, antibiotics, antibiotic susceptibilities

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1. INTRODUCTION

The antibiotic resistance trend of *P. aeruginosa* is becoming increasingly severe. According to the CDC, in the United States in 2019, *P. aeruginosa* was associated with 32,600 infections and approximately 2,700 deaths [1]. In Vietnam, healthcare facilities are experiencing a rising prevalence of antibiotic resistance in *P. aeruginosa* compared to global trends. Notably, *P. aeruginosa* exhibits high resistance to the broad-spectrum Carbapenem class of antibiotics, which is commonly used to treat severe and multidrug-resistant infections [2,3].

Given this practical need, the study “Antibiotic resistance situation of *Pseudomonas aeruginosa* at Children’s Hospital 2, Ho Chi Minh City from September 1, 2023, to May 31, 2024” is being conducted to help the medical team at Children’s Hospital 2 understand the antibiotic resistance status of *P. aeruginosa*, select appropriate antibiotics for treatment, and control infections.

2. SUBJECTS

Pediatric patients who underwent culture, isolation, and antibiotic susceptibility testing for *P. aeruginosa* at Children’s Hospital 2 from September 1, 2023, to May 31, 2024.

3. RESEARCH METHODS

This is a retrospective cross-sectional descriptive study, based on data and information collected from the antibiotic susceptibility test results stored at the Microbiology Department of Children’s Hospital 2.

Data entry and analysis were performed using Microsoft Excel 2013.

The study adheres to biomedical ethics and was conducted after obtaining approval from the Ethics Committee of Pham Ngoc Thach University of Medicine and Children’s Hospital 2.

Table 1: List of antibiotics and MIC concentrations used to assess the antibiotic susceptibility of *P. aeruginosa*[20]

ANTIBIOTICS	MIC (µg/mL)		
	Sensitive (S≤)	Intermediate (I)	Resistant (R≥)
COMBINATION β- LACTAM			
Ampicillin - Sulbactam	8/4	16/8	32/16
Piperacillin - Tazobactam	16/4	32/4	64/4
CEPHALOSPORINS			
Cefepime	8	16	32
Ceftriaxone	1	2	4
Cefotaxime	1	2	4
Ceftazidime	8	16	32
CARBAPENEMS			
Imipenem	2	4	8
Meropenem	2	4	8
AMINOGLYCOSIDES			
Gentamicin	1	4	8
Amikacin	4	8	16
FLUOROQUINOLONES			
Ciprofloxacin	0,5	1	2
Levofloxacin	1	2	4
FOLATE PATHWAY INHIBITORS			
Trimethoprim - Sulfamethoxazole	2/38	-	4/76
POLYPEPTIDES			
Colistin		2	4

4. RESULTS

4.1 Distribution characteristics of isolated *P. aeruginosa*

Table 2: Distribution characteristics of isolated *P. aeruginosa*

CHARACTERISTICS	FREQUENCY	PERCENTAGE (%)
Age group		
0 - 11 months	205	52,3*
12 - 59 months	104	26,5
≥ 60 months	83	21,2**
Total	392	100
Gender		
Male	235	59,9*
Female	157	40,1

Total	392	100
Departments		
Intensive Care Unit	58	14,8
Respiratory	94	24,0*
Neonatology	20	5,1
Cardiology	22	5,6
Emergency	48	12,2
Infectious Diseases	3	0,8**
Surgery	13	3,3
Internal Medicine	20	5,1
Oncology	7	1,8
Neurology	51	13,0
Gastroenterology	12	3,1
Others	44	11,2
Total	392	100
Specimens		
Lower respiratory tract	324	82,5*
Upper respiratory tract	01	0,3
Blood	09	2,3
Urine	09	2,3
Pus	41	10,5
Cerebrospinal fluid	0	0,0**
Sterile body fluids	06	1,5
Genital	01	0,3
Others (Catheter)	01	0,3
Total	392	100
Diagnosis		
Pneumonia	306	79,1*
Meningitis	3	0,7
Sepsis	7	1,8
Urinary tract infection	7	1,8
Skin infection	5	1,3
Wound infection	11	2,8
Appendicitis peritonitis	15	3,9
Surgical site infection	10	2,6
Vaginal infection	1	0,3**
Gastrointestinal infection	2	0,5
Cancer	6	1,6

Burns	7	1,8
Others	7	1,8
Total	392	100

*Highest

**Lowest

P. aeruginosa was most commonly isolated in children aged 0 – 11 months (52.3%) and least commonly in children aged 60 months and older (21.2%). The isolation rate in males (59.9%) was higher than in females (40.1%). The Respiratory Department had the highest isolation rate (24.0%), while the Infectious Diseases Department had the lowest (0.8%). Lower respiratory tract specimens accounted for the highest isolation rate (82.5%), while no cases were recorded in cerebrospinal fluid during the study period. Pediatric patients diagnosed with pneumonia had the highest rate (79.1%), while vaginal infections accounted for only 0.3%.

4.2 Antibiotic resistance rate of *P. aeruginosa* isolated from September 1, 2023, to May 31, 2024

Table 3: Antibiotic resistance rate of *P. aeruginosa* isolated at Children’s Hospital 2 from September 1, 2023, to May 31, 2024

ANTIBIOTICS	Sensitive (%)	Intermediate (%)	Resistant (%)
Piperacillin-Tazobactam	70,4	3,8	25,8
Ceftazidime-Avibactam	80,1	0,3	19,6
Ceftazidime	66,3	3,1	30,6
Cefepime	71,2	5,1	23,7
Imipenem	48,5	13,8	37,8*
Meropenem	63,8	4,6	31,6
Colistin	0	95,9	4,1**
Gentamicin	68,9	1,5	29,6
Amikacin	80,4	5,9	13,8
Ciprofloxacin	61,5	3,6	34,9

*Highest

**Lowest

The antibiotic resistance rate of *P. aeruginosa* was highest for the antibiotic Imipenem (37.8%), followed by Ciprofloxacin (34.9%) and Meropenem (31.6%) (n=124). The lowest antibiotic resistance rate of *P. aeruginosa* was for the antibiotic Colistin (4.1%).

4.3 Distribution of antibiotic resistance rates of *P. aeruginosa* according to various factors at Children’s Hospital 2 from September 1, 2023, to May 31, 2024.

Table 4: Distribution of antibiotic resistance rates of *P. aeruginosa* by pediatric age groups

ANTIBIOTICS	0 - 11 months	12 - 59 months	≥ 60 months
Piperacillin-Tazobactam n=101	50,5*	23,8	25,7
Ceftazidime-Avibactam n=77	42,9*	31,1	26,0
Ceftazidime n=120	45,8*	28,3	25,9
Cefepime n=93	46,2*	26,9	26,9
Imipenem n=148	48,0*	27,7	24,3
Meropenem n=124	45,2*	29,0	25,8
Colistin n=16	31,2	25,0	43,8*
Gentamicin n=116	47,4*	27,6	25,0
Amikacin n=54	37,0*	35,2	27,8
Ciprofloxacin n=137	52,8*	27,0	21,2

*Highest

**Lowest

Pediatric patients aged 0 – 11 months had the highest resistance rates for 9 out of 10 antibiotics studied, except for Colistin, which had the highest resistance rate of 43.8% in the group aged ≥ 60 months.

Table 5: Distribution of antibiotic resistance rates of *P. aeruginosa* by treatment departments (1)

ANTIBIOTICS	RESPIRATORY	INTERNAL MEDICINE	CARDIOLOGY	NEUROLOGY	EMERGENCY	INFECTIOUS DISEASES
Piperacillin-Tazobactam n=101	18,8	4,0	4,9	10,9	10,9	0,0
Ceftazidime-Avibactam n=77	18,2	3,9	5,1	10,4	10,4	0
Ceftazidime n=120	18,3	5,0	5,8	11,7	10,8	0,8
Cefepime n=93	19,4	4,3	6,4	10,8	9,7	0
Imipenem n=148	20,3	3,4	6,7	12,2	11,5	0
Meropenem n=124	17,7	4,1	5,6	9,7	12,9	0
Colistin n=16	12,4	6,3	6,3	18,8*	0	0
Gentamicin n=116	19,0	5,2	6,0	11,2	9,5	0,9
Amikacin n=54	14,8	3,7	3,7	11,1	9,3	1,9
Ciprofloxacin n=137	21,9	5,8	6,6	10,2	7,3	0,7

*Highest

Table 6: Distribution of antibiotic resistance rates of *P. aeruginosa* by treatment departments (2)

ANTIBIOTICS	INTENSIVE CARE UNIT	ONCOLOGY	SURGERY	GASTROENTEROLOGY	NEONATOLOGY	OTHERS
Piperacillin-Tazobactam n=101	25,7*	3,0	5,0	1,0	1,0	148
Ceftazidime-Avibactam n=77	29,9*	3,9	6,5	0	1,3	104
Ceftazidime n=120	22,5*	3,4	4,2	0,8	3,4	133
Cefepime n=93	25,8*	3,2	4,3	0	3,2	129
Imipenem n=148	25,0*	2,6	4,1	1,4	2,0	10,8
Meropenem n=124	27,4*	3,3	4,0	0,8	2,4	12,1
Colistin n=16	0	124	124	6,3	6,3	188*
Gentamicin n=116	25,9*	3,4	4,3	0,9	1,6	12,1
Amikacin n=54	27,8*	7,4	5,6	0	1,8	13,0
Ciprofloxacin n=137	24,8*	2,9	4,5	2,2	2,2	10,9

*Highest

The Intensive Care Unit had the highest antibiotic resistance rates for *P. aeruginosa* for most antibiotics, except for Colistin (0%). The resistance rates for Ceftazidime-Avibactam (29.9%) and Amikacin (27.8%) were highest here. Conversely, the Neurology Department and the group of other departments had the highest Colistin resistance rate (18.8%). The Infectious Diseases Department recorded the lowest resistance rates, with the highest being Amikacin (1.9%) and no resistance found

Table 7: Distribution of antibiotic resistance rates of *P. aeruginosa* by cultured specimens

ANTIBIOTICS	LOWER RESPIRATORY TRACT	PUS	BLOOD	URINE	STERILE BODY FLUIDS	CEREBROSPINAL FLUID	OTHERS
Piperacillin-Tazobactam n=101	80,2*	13,8	1,0	3,0	1,0	0	1,0
Ceftazidime-Avibactam n=77	79,2*	13,0	1,3	3,9	1,3	0	1,3
Ceftazidime n=120	78,3*	14,2	1,7	4,2	0,8	0	0,8
Cefepime n=93	79,6*	14,0	1,1	4,2	0	0	1,1
Imipenem n=148	84,3*	10,1	1,3	2,5	0,6	0	1,2
Meropenem n=124	82,3*	11,3	1,6	3,2	0,8	0	0,8
Colistin n=16	62,5*	18,8	6,3	12,4	0	0	0
Gentamicin n=116	81,0*	12,9	1,7	3,5	0	0	0,9
Amikacin n=54	74,1*	14,8	3,6	5,6	0	0	1,9
Ciprofloxacin n=137	81,8*	11,7	1,5	3,6	0,7	0	0,7

*Highest

P. aeruginosa isolated from lower respiratory tract specimens showed the highest resistance rates among the 10 antibiotics studied. Of these, Imipenem had the highest resistance rate (84.3%), followed by Meropenem (82.3%), and Colistin had the lowest resistance rate (62.5%).

Table 8: Distribution of antibiotic resistance rates of *P. aeruginosa* by diagnosis (1)

ANTIBIOTICS	PNEUMONIA	MENINGITIS	SEPSIS	URINARY TRACT INFECTION	SKIN INFECTION	WOUND INFECTION
Piperacillin-Tazobactam n=101	76,5*	0	2,0	2,0	2,0	4,1
Ceftazidime-Avibactam n=77	76,0*	0	4,0	1,3	1,3	2,7
Ceftazidime n=120	74,4*	0	2,5	2,5	2,5	4,3
Cefepime n=93	75,8*	0	3,3	2,2	2,2	3,3
Imipenem n=148	79,9*	0	2,1	2,1	1,4	2,8
Meropenem n=124	78,5*	0	1,6	2,5	1,6	3,4
Colistin n=16	62,5*	0	0	6,3	0	6,3
Gentamicin n=116	76,1*	0	2,7	1,8	1,8	2,7
Amikacin n=54	69,2*	0	3,9	1,9	1,9	5,8
Ciprofloxacin n=137	78,4*	0	2,2	2,2	1,5	4,5

Table 9: Distribution of antibiotic resistance rates of *P. aeruginosa* by diagnosis (2)

ANTIBIOTICS	APPENDICITIS PERITONITIS	SURGICAL SITE INFECTION	VAGINAL INFECTION	GASTROINTESTINAL INFECTION	CANCER	BURNS	OTHERS
Piperacillin-Tazobactam n=101	1,0	3,2	1,0	1,0	2,0	4,2	1,0
Ceftazidime-Avibactam n=77	0	2,7	1,3	0	2,7	5,3	2,7
Ceftazidime n=120	1,7	2,6	0,9	0,9	2,6	3,4	1,7
Cefepime n=93	1,1	2,2	1,1	0	2,2	4,4	2,2
Imipenem n=148	1,4	2,8	0,6	0,6	2,1	2,8	1,4
Meropenem n=124	0,8	2,5	0,8	0,8	2,5	3,4	1,6
Colistin n=16	6,3	6,3	0	0	12,3	0	0
Gentamicin n=116	1,8	3,5	0,8	0,8	2,7	3,5	1,8
Amikacin n=54	0	1,9	1,9	1,9	5,8	3,9	1,9
Ciprofloxacin n=137	0	2,2	0,7	1,5	2,2	3,1	1,5

*Highest

Among 392 pediatric patients infected with *P. aeruginosa*, pneumonia was the most common symptom. The resistance rate of the bacterium to all 10 antibiotics studied was high, particularly for Imipenem (79.9%), Meropenem (78.5%), and Ciprofloxacin (78.4%), while Colistin had the lowest resistance rate (62.5%).

5. DISCUSSION

5.1 Rate of *P. aeruginosa* infection in pediatric patients by age groups

P. aeruginosa was predominantly isolated

in the 0–11 months age group (52.3%), which was lower in older age groups. This finding aligns with Weichun Huang's (2023) research at the Shanghai Children's Medical Center, which reported the highest isolation rate of *P. aeruginosa* in children aged 0–11.9 months (62.8%) compared to those aged 1–3 years (15.5%) and over 3 years (21.1%).[4] This discrepancy might be attributed to the immature immune system in infants, making this age group more susceptible to bacterial infections, especially antibiotic-resistant bacteria like *P. aeruginosa*. [5]

5.2 Rate of *P. aeruginosa* infection in pediatric patients by departments

At Children's Hospital 2, *P. aeruginosa* was most frequently isolated in the Respiratory Department (24.0%), followed by the Intensive Care Unit (14.8%) and the Emergency Department (12.2%). The rate was significantly lower in departments such as Infectious Diseases (0.8%) and Oncology (1.8%).

Comparing this with Nguyen Huu Ngoc Tuan's (2024) study at Nguyen Tri Phuong Hospital, the highest isolation rate was recorded in the Internal Medicine Department (53.8%–62.9%), whereas Nguyen Thi Doan Trinh's (2023) study at C Da Nang Hospital indicated the highest isolation rate in the Intensive Care and Anti-Poisoning Department (41.9%). [6],[7] These differences might be due to the patients' pathological characteristics, invasive procedures, and infection control measures among departments and hospitals.

5.3 Rate of *P. aeruginosa* isolation in different types of clinical specimens

Among the 392 isolated strains of *P. aeruginosa*, 324 strains (82.5%) were collected from lower respiratory tract specimens, significantly higher than other types of specimens such as pus (10.5%),

blood (2.3%), and urine (2.3%). There were no isolates from cerebrospinal fluid and genital specimens.

Comparing previous studies: Ann Fan Yang et al. (2023) in the United States reported the highest isolation rate of *P. aeruginosa* from respiratory specimens in 2019 (60%) which decreased to 32% in 2020. [8] In Vietnam, Nguyen Huu Ngoc Tuan et al. (2024) at Nguyen Tri Phuong Hospital (Ho Chi Minh City) recorded the highest isolation rate from respiratory specimens during 2020–2023, with respective rates of 64.4%, 50.3%, 43.2%, and 42.4%. [7] In Hai Phong, Luu Thi Nga et al. (2024) also reported the highest isolation rate from respiratory specimens, reaching 48.27%. [9]

These results continue to confirm that lower respiratory tract specimens are the primary source of *P. aeruginosa* isolates in hospital environments.

5.4 Antibiotic resistance rate of *P. aeruginosa* from September 1, 2023 to May 31, 2024

Based on antibiotic susceptibility testing results from 392 pediatric patients at Children's Hospital 2 (September 2023 - May 2024), this study evaluates the resistance rate of *P. aeruginosa* to various antibiotics. The results showed that the resistance rates to Ceftazidime and Cefepime were 30.6% and 23.7%, respectively, consistent with Taghreed A. Hafiz's study in Riyadh, Saudi Arabia (26.1% and 24.3%) and Nguyen Huu Ngoc Tuan's study in Ho Chi Minh City (25.6%), but lower compared to Nguyen Thi Huyen's study in Thai Nguyen (38.83% and 45.45%). [10],[7],[11]

The resistance rates to Imipenem and Meropenem in this study were 37.8% and 31.6%, respectively, higher than in Taghreed A. Hafiz's studies (29.5% and 25.6%), [10] Nguyen Huu Ngoc Tuan's studies in Ho Chi

Minh City (16.2% - 22.8% for Imipenem; 20.9% - 28.8% for Meropenem), [7] but lower than in Le Van Cuong's study in Thanh Hoa (52%)[12] and Nguyen Thi Doan Trinh's study in Da Nang (41.9% and 44.2%).[6]

Piperacillin-Tazobactam showed a resistance rate of 25.8%, similar to studies in the United States (24.4%) and Ethiopia (26.7%).[8],[13] However, this rate was higher than studies in Vietnam, such as Nguyen Thi Doan Trinh's study in Da Nang (11.6%) and Nguyen Huu Ngoc Tuan's study in Ho Chi Minh City (7.0% - 13.2%). [6],[7],[9]

For Ceftazidime-Avibactam, the resistance rate was 19.6%. Mendes Pedro's study in Portugal recorded a higher rate (28.5%), whereas a study in Poland reported a lower rate (6.3%).[14],[15]

Ciprofloxacin had a resistance rate of 34.9%, higher than some international studies [8],[10],[13] but lower than studies in Vietnam. [6],[7],[9],[11],[12],[16]

Amikacin had the lowest resistance rate among Aminoglycosides at 13.8%, lower compared to both international and domestic studies. [6-13],[16],[17] Conversely, the resistance rate for Gentamicin was 29.6%, higher than Nguyen Huu Ngoc Tuan's study in Ho Chi Minh City (25.5%) but lower than studies in Thanh Hoa, Da Nang, and Can Tho.[6],[7],[12],[16]

Colistin continued to show the best efficacy with a resistance rate of only 4.1%, higher than the study in Saudi Arabia (1.1%) but lower than studies in Thanh Hoa (8.3%) and Da Nang (16.3%).[12],[6],[10]

The differences in the antibiotic resistance rates of *P. aeruginosa* at Children's Hospital 2 (September 1, 2023 - May 31, 2024) compared to other studies can be explained by two main factors. Firstly,

the selective pressure of antibiotics at the hospital, differences in antibiotic usage strategies, and infection control measures in different geographical regions. Secondly, besides natural resistance mechanisms, *P. aeruginosa* can acquire resistance genes through plasmids and horizontal gene transfer between bacterial populations, rapidly increasing the spread of resistance. The study's results not only provide practical data on the antibiotic resistance situation of *P. aeruginosa* but also emphasize the importance of infection control and rational antibiotic use in hospital settings.

5.5 Distribution of antibiotic resistance rates of *P. aeruginosa* based on several factors

In the 0-11 months age group, the isolation rate and antibiotic resistance rate of *P. aeruginosa* were highest for most antibiotics, including Cephalosporins (Cefepime, Ceftazidime), Carbapenems (Imipenem, Meropenem), Aminoglycosides (Gentamicin, Amikacin), and Fluoroquinolones (Ciprofloxacin). Antibiotics combined with inhibitors, such as Ceftazidime-Avibactam and Piperacillin-Tazobactam, also recorded high resistance rates. Colistin, however, exhibited the highest resistance rate in the ≥ 60 months age group, reaching 43.8%. This may be due to the natural decline in immunity in children combined with hospital environmental factors.

The antibiotic resistance rates of *P. aeruginosa* for lower respiratory tract specimens ranged from 62.5% to 84.3% for the 10 antibiotics studied, including Piperacillin-Tazobactam, Ceftazidime-Avibactam, Ceftazidime, Cefepime, Imipenem, Meropenem, Colistin, Gentamicin, Amikacin, and Ciprofloxacin.

In the Intensive Care Unit, *P. aeruginosa*

exhibited the highest resistance rates, ranging from 22.5% to 29.9% for 9 out of 10 antibiotics, except for Colistin. Patients in this department often undergo numerous invasive medical procedures and surgeries, leading to immunosuppression and the disruption of natural protective barriers, providing an opportunity for *P. aeruginosa* to invade and cause infections. Severe illnesses and immunosuppression in these patients also contribute to the increased virulence of the bacteria.[18]

In clinical diagnoses, *P. aeruginosa* in pediatric pneumonia patients showed the highest antibiotic resistance rates compared to other conditions such as septicemia, urinary tract infections, and burns. The resistance rates reached 70% or higher for Beta-lactam antibiotics (Ceftazidime, Cefepime, Imipenem, Meropenem), Aminoglycosides (Gentamicin), Quinolones (Ciprofloxacin), and antibiotics combined with inhibitors (Ceftazidime-Avibactam, Piperacillin-Tazobactam), with Colistin resistance at 62.5%. Similarly, Nguyen Thanh Nghiem's study (2021–2022) at Can Tho City General Hospital also reported high resistance rates from 60% to 86% for these antibiotics, except for Colistin, which maintained 100% efficacy.[19]

6. CONCLUSION

The study shows that *P. aeruginosa* is predominantly isolated in young pediatric patients, especially those under 1 year old, with high rates in the Respiratory Department and from lower respiratory tract specimens. High levels of antibiotic resistance were recorded for Carbapenem antibiotics (*Imipenem*, *Meropenem*), Ceftazidime, Ciprofloxacin, and Gentamicin, highlighting the need to optimize antibiotic use and strengthen infection control measures. Young pediatric

patients, pneumonia patients, and cases in the Intensive Care Unit should be closely monitored, and strict antimicrobial control strategies should be applied. Preserving the efficacy of last-resort antibiotics, including Colistin, Amikacin, Ceftazidime-Avibactam, and Piperacillin-Tazobactam, alongside ongoing research on resistance mechanisms and therapeutic strategies, is crucial for strengthening infection control and management.

To improve treatment effectiveness, more detailed studies on Colistin resistance in patients aged 60 months or older and in the Intensive Care Unit, as well as further research on infection control measures and antibiotic management for Imipenem resistance, are needed.

Additionally, expanding the research scope to assess antibiotic resistance trends of *P. aeruginosa* over the years, conducting multi-center studies in various regions, and analyzing the relationship between clinical factors such as broad-spectrum antibiotic use, duration of antibiotic treatment, and underlying diseases of pediatric patients will provide crucial scientific evidence for developing infection control strategies and optimizing future treatments.

7. ABBREVIATIONS

P. aeruginosa: *Pseudomonas aeruginosa*

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