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Original Article

Evaluation of Gram-negative hospital-acquired infections and antibiotic resistance in the pediatric intensive care unit

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Abstract

Introduction: We retrospectively analyzed the frequency of healthcare-associated infections (HAIs), infection sites, Gram-negative microorganisms in the cultures, and antibiotic resistance patterns; recorded in the pediatric intensive care unit (PICU); between 2017 and 2023; based on the records in our hospital's infection control surveillance system. Our aim was to determine the state of infections over the years and the status of antibiotic resistance.

Methodology: Medical records of PICU patients, between 1 January 2017 and 31 July 2023, whose cultures were identified to have Gram-negative bacterial growth, were evaluated retrospectively.

Results: A total of 125 nosocomial infections were recorded. *Pseudomonas aeruginosa* and *Klebsiella pneumoniae* were the most frequently identified and had equal growth rates in blood culture. *K. pneumoniae* were most frequently identified in the central venous catheter (CVC). Mortality was significantly higher for patients with fungal growth, congenital diseases, and males ($p < 0.05$); except in patients with CVC. Patients with congenital diseases had a shorter median survival time (65 days) compared to chronic disease patients (151 days; $p < 0.005$). Cox regression analysis indicated that comorbidity was a significant risk factor for survival time. The risk of mortality was 3.074 times higher in patients with congenital disease compared with chronic disease patients (HR = 3.074; 95% CI: 1.577–5.995). Gender had a significant relationship with mortality; however, survival times did not differ between genders ($p > 0.05$).

Conclusions: Gram-negative bacterial infections are becoming more prevalent in intensive care units, and effective control and prevention policies are needed for these infections.

Key words: antibiotic; culture; microorganism; pediatric.

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Introduction

Healthcare-associated infection (HAI) is defined as an infection that was not present or incubating in the patient at the time of admission to the hospital or another healthcare facility, but emerged during the patient's care process [1]. HAIs are also known as nosocomial infections [2]. HAIs are the most serious unexpected complication that can occur during patient care, and a complete solution to this health issue has not yet been achieved by any institution, clinic, or country [1]. According to the World Health Organisation (WHO), the prevalence of HAI in developing countries is 15.5 cases per 100 patients, while in developed countries this rate is 7.6 cases per 100 patients. In this scenario, it is very important to emphasise that our country, like other countries, faces various challenges in preventing healthcare-related infections. These infections are more frequent in pediatric patients and act as a catalyst for numerous complications in hospitalised children [2]. Since HAIs develop within healthcare settings, they can significantly prolong hospital stays. These infections tend to be more severe than other illnesses, including common childhood diseases (eg. viral infections such as hand-foot-and-mouth disease, and respiratory infections such as bronchiolitis), chronic conditions (eg. asthma), and other bacterial infections (eg. urinary tract infections). This increases treatment costs and leads to high morbidity and mortality rates. Patients in intensive care units are particularly vulnerable to HAIs due to their critical clinical conditions and frequent exposure to invasive procedures [3].

There are several recent studies examining the incidence of nosocomial infections in pediatric intensive care units (PICUs). For instance, a study conducted in 2022 reported that 14.8% of the 725 pediatric patients admitted to the PICU developed nosocomial infections. The most commonly reported

types of infections included central line-associated bloodstream infections (CLABSI) and ventilator-associated infections (VAP) [4].

In this study, we aimed to retrospectively analyze the frequency of HAIs, infection sites, microorganisms identified in cultures, and antibiotic resistance in patients followed up in our PICU between 2017 and 2023.

Methodology

This study was conducted following the guidelines of the Declaration of Helsinki, and was approved by the Toros University Ethics Committee (registration number DEISC-PR-10.08.2023/58). Patients between the ages of 1 month and 18 years, who were brought to the emergency clinic; or hospitalized in wards or external centers, but needed advanced life support during follow-up; or postoperative patients; were accepted to the PICU unit. All internal and surgical hospitalized pediatric patients between the ages of 1 month and 18 years who were transferred to the PICU were consecutively included in the study.

The inclusion criteria were patients admitted to the PICU between 1 January 2017 and 31 July 2023, whose cultures showed Gram-negative bacterial growth, and had complete medical records. The exclusion criteria were patients admitted to departments outside the PICU or transferred from the PICU, patients whose cultures did not show Gram-negative bacterial growth, and patients with incomplete records or insufficient data for analysis. The medical records of patients who were admitted and treated in our unit between 1 January 2017 and 31 December 2023 and stayed for more than 48 hours were retrospectively examined.

Definitions

Infections that were not present at the time of admission to the hospital, or were not in the incubation period (i.e. developed 48 hours after hospitalization) were defined as HAIs

The diagnosis of HAI was made by a nurse and a pediatric infectious diseases specialist, who were employed by the Hospital Infectıon Control Committee (HICC) for active surveillance of infections based on the HICC criteria for HAIs. Based on their criteria, infections that developed in patients while receiving healthcare services during their hospital stay, and > 48 hours after admission, were included. According to the Centers for Disease Control and Prevention (CDC), HAIs are infections that are caused by pathogens or toxins that arise from the healthcare environment and are not present or incubating at the time of the patient's admission. These infections are not considered as complications or extensions of pre-existing conditions but rather as new infections. The CLABSI, VAP, urinary tract infections (UTI), and HAI were defined according to the CDC surveillance criteria [5].

During the study period, HAIs in 125 children in the Mersin Training and Research Hospital PICU were laboratory-proven. Demographic, clinical, and laboratory information of the cases was obtained retrospectively from the hospital information technology system. Patient information from the files, clinical findings, and laboratory results were entered into SPSS 27 (Released 2020, IBM Corp, Armonk, NY, USA).

All samples (blood, urine, endotracheal aspiration, bronchoalveolar lavage) were subjected to microbiological examination using standard methods in the Microbiology Laboratory of Mersin Training and Research Hospital PICU. The blood cultures were processed on the automated blood culture system. The samples were identified by conventional tests and automated microbiology system (VITEK 2, Biomerieux, France). The risk factors were venous/arterial catheter use, such as nasogastric catheter, urinary catheter, central venous catheter (CVC); intubation tube; tracheostomy; and surgery. Susceptibility and resistance of Gram-negative bacteria to gentamicin, ciprofloxacin, cefepime, meropenem, piperacillin-tazobactam, amikacin, trimethoprim-sulfamethoxazole, colistin, tigecycline, and ceftazidime-avibactam were investigated.

Statistical analysis

The jamovi project (2024, version 2.5) was used for statistical analyses. The Shapiro Wilk test was used for checking normality. Hospitalization and age were described with median, minimum, and maximum values. Categorical data were presented as frequency and percentages (n (%)).

The Chi square test of independence was used to determine if there was an association between categorical variables. The Chi square homogeneity test was used to determine whether the distribution of microorganisms at the site of growth, their resistance according to antibiotic type, and their distribution according to the years were similar.

The duration of hospitalization was recorded in days until discharge, and mortality was followed during this period. The Kaplan-Meier analysis was performed to estimate the survival time of the patients during the follow-up period and the Kaplan-Meier curve was drawn. The log-rank test was used to compare survival

times between the two groups. A Cox regression analysis was performed for the effect of risk factors on survival time, and the hazard ratio, and 95% confidence interval for the hazard ratio was calculated.

Results

A total of 7,534 patients were hospitalized in the PICU during the study period, and the infections in 125 of them were considered as HAIs. The other patients were excluded because they did not meet the CDC criteria. Our study evaluated the 125 cases registered in the infection control surveillance system between 2017 and 2023. Among the 125 patients, 52 (41.6%) were female and 73 (58.4%) were male. The average age of the patients was 52 months (minimum 9 months, maximum 216 months), and the average hospital stay was 46 days (range: 2 to 223 days). Among the patients, 46 (36.8%) had congenital diseases (congenital heart disease (CHD), respiratory conditions, neurological disorders, metabolic and genetic disorders) and 63 (50.4%) had underlying chronic diseases (chronic respiratory disorders; cerebral palsy; endocrine disorders, especially diabetic ketoacidosis etc). When the diagnoses leading to hospitalization were examined, it was determined that 70 (56%) had respiratory failure, 26 (20.8%) had neurological conditions, and 22 (17.6%) had sepsis. Other hospitalization diagnoses included drowning, traffic accidents, and burns.

The mortality rate after hospitalization was 33.6% (Table 1). Of the 125 laboratory-proven HAIs during the study period, 61 (48.8%) were identified as CLABSI, 20 (16%) as VAP, and 11 (8.8%) as hospital-acquired UTI. Among the CLABSI cases, 33 (26.4%) were CVC-related infections. The most frequently isolated agents in all samples (traceal aspirate/bronchoalveolar lavage (BAL), blood, urine, and CVC) taken from patients were *Pseudomonas* spp. in 36 (28.8%) patients, *Klebsiella* spp. in 31 (24.8%) patients, *Acinetobacter baumannii* in 21 (16.8%) patients, and *Stenotrophomonas* in 10 (8%) patients. *Burkholderia* spp. was identified in 9 (7.2%) patients, *Serratia* spp. in 5 (4%) patients, *E. coli* in 4 (3.2%) patients, and other bacteria in 9 (7.2%) patients. When evaluated in terms of interventions, it was determined that 124 (99.2%) patients had a urinary catheter, 111 (88.8%) were on mechanical ventilation, and 116 (92.8%) had a CVC. Other medical interventions are listed in Table 1. *Pseudomonas* spp. had the highest growth rate in tracheal aspirate/BAL. *Pseudomonas* spp. and *Klebsiella* spp. had the highest and equal growth rates in peripheral and central catheter blood cultures. *Klebsiella* spp. had the highest growth rate in CVC (Table 2).

A. baumannii isolates were resistant to all three antibiotics, meropenem, amikacin and ciprofloxacin, with a rate of up to 54.8%; and they were most sensitive to colistin, with a rate of 20.4%. Other antibiogram results and rates are presented in Table 3.

Table 1. Comparison of demographic and clinical characteristics of cases with healthcare associated infection (HAI).

Characteristics	n	%
Age (months), median (min–max)	52 (9–216)	
Hospitalization (day), median (min–max)	46 (2–223)	
Gender		
Female	52	41.6
Male	73	58.4
Underlying disease		
Congenital diseases		
Congenital heart diseases	19	15.2
Intestinal malformations	11	8.8
Neural tube defect	13	10.4
Down syndrome	3	2.4
Chronic diseases		
Cerebral palsy/epilepsy	41	32.8
Chronic lung disease	12	9.6
Metabolic disease	7	5.6
Primer immünodeficiency	3	2.4
Malignancy	1	0.78
Other*	15	12.0
Reason for PICU admission [n (%)]		
Lower respiratory tract infections	70	56.0
Neuromuscular disorders	26	20,8
Septicemia	22	17.6
Other**	7	5.6
Medical devices		
Yes	93	74.4
No	32	25.6
Isolated microorganism		
Pseudomonas spp.	36	28.8
Klebsiella pneumoniae	31	24.8
Acinetobacter baumannii	21	16.8
Escherichia coli	10	8.0
Serratia spp..	4	3.2
Stenotrophomonas maltophilia	5	.,0
Burkholderia spp	9	7.2
Other***	9	7.2
Isolation site		
Tracheal aspirate/ bronchoalveolar lavage	20	16.0
Urine	11	8.8
Blood	61	48.8
Central venous catheter	33	26.4
Mortality		
Yes	42	3.,6
No	83	66.4
Central venous catheter		
Yes	116	92.8
No	9	7.2
Urinary catheter		
Yes	124	99.2
No	1	0.8
Mechanical ventilation		
Yes	111	88.8
No	14	11.2

Other*: burn, drowning, traffic accident; Other**: trauma, post-op surgery, metabolic causes; Other***: *Enterococcus spp. Proteus vulgaris, Enterobacter spp.* medical devices; *tracheostomy/endotracheal tube, central catheter, urinary catheter, ventriculo-peritoneal shunt. PICU: pediatric intensive care unit.

Table 2. Microorganisms detected in healthcare associated infections (HCAIs) and their distribution according to isolation sites.

Isolated organisms	Site of isolation			
	Tracheal aspirate/BAL n (%)	Urine n (%)	Blood n (%)	CVC n (%)
Pseudomonas aeruginosa	13 (65)	2 (18.2)	10 (30.3)	11 (18)
Klebsiella pneumoniae	2 (10)	6 (54.5)	10 (30.3)	13 (21.3)
Acinetobacter baumannii	4 (20)	0 (0)	6 (18.2)	11 (18)
Escherichia coli	1 (5)	0 (0)	0 (0)	9 (14.8)
Serratia spp..	0 (0)	2 (18.2)	1 (3)	1 (1.6)
Stenotrophomonas maltophilia	0 (0)	1 (9.1)	1(3)	3 (4.9)
Burkholderia spp	0 (0)	0 (0)	2 (.,1)	7 (11.5)
Other *	0 (0)	0 (0)	3 (9.1)	6 (9.8)
	$p = 0.0004$	$p = 0.147$	$p = 0.0025$	$p = 0.025$

BAL: bronchoalveolar lavage; CVC: central venous catheter; Other * *Enterococcus spp. Proteus vulgaris, Enterobacter spp.*

Table 3. Antibiotic sensitivity based on microorganism growth.

	Amikacin	Gentamicin	Ceftazidime	Ciprofloxacin	PIP-TAZ	Meropenem	TMP-SMX	Colistin	Tigecycline
Pseudomonas aeruginosa	35 (46.7)	24 (48)	18 (50)	17 (42.5)	15 (34.9)	19 (28.8)	8 (26.7)	32 (32.7)	9 (42.9)
Klebsiella pneumoniae	26 (34.7)	14 (28)	6 (16.7)	9 (22.,5)	13 (30.2)	26 (39.4)	9 (30.0)	31 (31.6)	4 (19.0)
Acinetobacter baumannii	4 (5.3)	3 (6)	2 (5.6)	1 (2.,5)	3 (7)	3 (4.5)	3 (10)	20 (20.4)	6 (28.6)
Escherichia coli	3 (4.0)	1 (2)	1 (2.8)	1 (2.5)	1 (2.3)	4 (6.1)	0 (0)	4 (4.1)	0 (0)
Serratia spp..	4 (5.3)	4 (8)	4 (11.1)	5 (12.5)	4 (9.3)	5 (7.6)	5 (16.7)	1 (1)	1 (4.,8)
Stenotrophomonas maltophilia	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0.0)	10 (58.8)	0 (0)	0 (0)
Burkholderia spp	0 (0)	1 (2)	0 (0)	2 (5)	2 (4.7)	5 (7.6)	0 (0)	4 (4.1)	0 (0)
Other*	3 (4)	3 (6)	5 (13.9)	5 (12.5)	5 (11.6)	4 (6.1)	5 (16.7)	6 (6.,1)	1 (4.8)
Total	75 (100)	50 (100)	36 (100)	40 (100)	43 (100)	66 (100)	40 (100)	98 (100)	21 (100)
	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$	$p = 0.347$	$p < 0.0001$	$p = 0.025$

PIP-TAZ: piperacillin tazobactam; TMP-SMX: trimethoprim-sulfamethoxazole; Other*, *Enterococcus* spp. *Proteus vulgaris*, *Enterobacter* spp. The data is summarized by n (%).

Table 4. Distribution of antibiotic resistance based on microorganism growth.

	Amikacin	Gentamicin	Ceftazidime	Ciprofloxacin	PIP-TAZ	Meropenem	TMP-SMX	Colistin	Tigecycline
Pseudomonas aeruginosa	1 (3.2)	0 (0)	11 (23.4)	5 (10.6)	8 (24.2)	8 (25.8)	2 (4.7)	2 (22.2)	1 (50)
Klebsiella pneumoniae	5 (16.1)	16 (42.1)	21 (44.7)	16 (34)	14 (42.4)	3 (9.7)	19 (44.2)	0 (0)	1 (50)
Acinetobacter baumannii	17 (54.8)	13 (34.2)	6 (12.8)	17 (36.2)	5 (15.2)	17 (54.8)	15 (34.9)	0 (0)	0 (0)
Escherichia coli	1 (3.2)	3 (7.9)	3 (6.4)	3 (6.4)	1 (3)	0 (0)	4 (9.3)	0 (0)	0 (0)
Serratia spp..	1 (3.2)	0 (0)	1 (2.1)	0 (0)	1 (3)	0 (0)	0 (0)	4 (44.4)	0 (0)
Stenotrophomonas maltophilia	0 (0)	0 (,0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0,0)	0 (0)
Burkholderia spp	1 (3.2)	1 (2.6)	3 (6.4)	2 (4.3)	2 (6.1)	1 (3.2)	1 (2.3)	2 (22.2)	0 (0)
Other*	5 (16.1)	5 (1.2)	2 (4.3)	4 (8.5)	2 (6.1)	2 (6.5)	2 (4.7)	1 (11,1)	0 (0)
Total	31 (100)	38 (100)	47 (100)	47 (100)	33 (100)	31 (100)	43 (100)	9 (100)	2 (100)
	$p < 0.0001$	$p = 0.0002$	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$	$p < 0.0001$	$p = 0.549$	--

PIP-TAZ: piperacillin tazobactam; TMP-SMX: trimethoprim sulfometaxazole; Other*: *Enterococcus spp. Proteus vulgaris, Enterobacter spp.* The data is summarized by n (%).

Table 5. PICU antimicrobial drug resistance by years (2017-2023).

Resistance	2017	2018	2019	2020	2021	2022	2023	Total
Amikacin	2 (6.5)	2 (6.5)	2 (6.5)	11 (35.5)	6 (19.4)	4 (12.9)	4 (12.9)	31 (100)
Gentamicin	4 (10.5)	4 (10.5)	2 (5.3)	13 (34.2)	9 (23.7)	4 (10.5)	2 (5.3)	38 (100)
Ceftazidime	9 (19.1)	3 (6.4)	1 (2.1)	15 (31.9)	12 (25.5)	4 (8.5)	3 (6.4)	47(100)
Cefepime	8 (19.0)	3 (7.1)	1 (2.4)	15 (35.7)	9 (21.4)	4 (9.5)	2 (4.8)	42 (100)
PIP-TAZ	6 (18.2)	3 (9.1)	1 (3)	10 (30.3)	6 (18.2)	3 (9.1)	4 (12.1)	33 (100)
Ciprofloxacin	5 (10.6)	5 (10.6)	2 (4.3)	15 (31.9)	10 (21.3)	5 (10.6)	5 (10.6)	47 (100)
Meropenem	1 (3.2)	2 (6.5)	1 (3.2)	15 (4.4)	5 (16.1)	4 (12.9)	3 (9.7)	31 (100)
TMP-SMX	5 (11.6)	3 (7)	1 (2.3)	15 (34.9)	10 (23.3)	5 (11.6)	4 (9.3)	43 (100)

PIP-TAZ: piperacillin tazobactam; TMP-SMX: trimethoprim sulfometaxazole. The data is summarized by n (%).

Table 6. Association of mortality with antibiotics, gender, central venous catheter and comorbidity.

	Mortality			
	Yes n (%)	**No n (%)**	**Total**	***p***
PIP-TAZ				
Sensitivity	22 (73.3)	38 (60.3)	60	0.220
Resistance	8 (26.7)	25 (39.7)	33	
Ciprofloxacin				
Sensitivity	20 (55.6)	44 (58.7)	64	0.756
Resistance	16 (44.4)	31 (41.3)	47	
Colistin				
Sensitivity	33 (91.7)	65 (91.5)	98	1.000
Resistance	3 (8.3)	6 (8.5)	9	
Meropenem				
Sensitivity	27 (77.1)	50 (68.5)	77	0.352
Resistance	8 (22.9)	23 (31.5)	31	
CVC				
Yes	38 (90.5)	78 (94)	116	0.483
No	4 (9.5)	5 (6)	9	
Gender				
Male	31 (42.5)	42 (57.5)	73	0.013
Female	11 (21.2)	41 (78.8)	52	
Comorbidity				
Congenital Diseases	23 (50)	23 (50)	46	0.005
Chronic Diseases	15 (23.8)	48 (76.2)	63	

CVC: central venous catheter; PIP-TAZ: piperacillin tazobactam.

When the antibiograms of *Pseudomonas* spp were examined, it was determined that the antibiotic to which it was most resistant was meropenem (25.8%), and it was most sensitive to gentamicin (48%). Other antibiogram results and rates are presented in Tables 3 and 4. When the antibiograms of *Klebsiella* species isolates were examined, they were most resistant to gentamicin, ceftazidime, ciprofloxacin and trimethoprim-sulfamethoxazole (88.9%); and were most sensitive to colistin (22.2%). Other antibiogram results are presented in Table 4. Carbapenem resistance was identified at 25.8% in *Pseudomonas* spp, 9.7% in *Klebsiella* spp., and 54.8% in *Acinetobacter* spp. Table 5 presents the 6-year general statistical trends in antibiotic resistance status. There were no statistically significant relationships between mortality, and antibiotics used ($p > 0.05$). Mortality was significantly higher in patients with congenital diseases, and males ($p < 0.05$), except in the case of CVC (Table 6). Patients with congenital diseases had a shorter median survival time (65 days) compared to patients with chronic diseases (151 days) ($p < 0,005$) (Table 7). Based on Cox regression results, comorbidity was identified as a significant risk factor for survival time. Congenital disease patients had a 3.074 times higher risk than chronic disease patients (HR = 3.074; 95% CI: 1.577–5.995) (Figure 1). Even though fungal growth and gender had significant relationships with mortality, the survival times did not differ ($p > 0.05$).

Figure 1. Patients with congenital disease had a shorter median survival time (65 days) compared to patients with chronic disease. The relevance of this result is that all included patients had Gram-negative growth and the cases were considered as nosocomial infections.

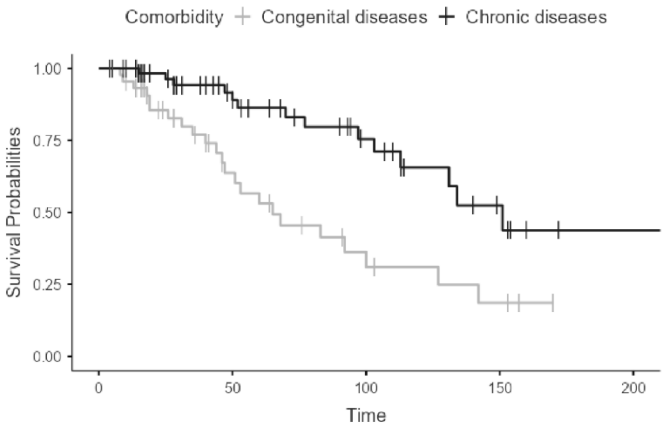

Table 7. Comparison of survival times associated with some clinical findings.

Comorbidity	**Survival time (days)**				
	Median (95% CI for survival time)	***p*[a]**	**β (se)**	**HR 95% CI for HR**	***p*[b]**
Congenital diseases	65 (30.0–99.7)	0.001	1.123 (0.341)	3.074 (1.577–5.995)	0.001
*Chronic diseases	151(119.7–182.3)				
Gender					
Male	100 (57.1–142.8)	0.235			
Female	127 (75.9–178.07)				

*Chronic diseases were the reference category for the Cox regression model. p^a was for log-rank test results. p^b was for the Cox regression model. CI: confidence interval; HR: hazard ratio.

Discussion

HAIs are important factors in assessing the quality of healthcare services. They are significant factors that increase both morbidity and mortality, as well as elevate costs, in both developed and developing countries [6]. In a recent systematic review and meta-analysis of HAIs, the global prevalence of HAIs was reported to be 0.14%, with annual increases of 0.06%. The highest prevalence of HAIs was reported in the African region, particularly in Central Africa. The study also found that intensive care units had some of the highest rates of HAIs, caused by common pathogens including *E. coli*, coagulase-negative staphylococci, and *Pseudomonas* spp. This underscores the significance of controlling HAIs in PICUs [7]. The infection rates are higher in developing countries, including our country [8]. The frequency of HAIs in our study was 17.2%, which is in accordance with the literature.

The use of invasive medical devices and surgical interventions significantly increases the risk of HAIs. Common HAIs include VAP, CLABSI, UTIs, and other bloodstream infections. These infections often arise from prolonged use of devices like CVCs, urinary catheters, and mechanical ventilators, which introduce potential for infection by facilitating the entry of pathogens into sterile body surfaces [9]. The most common HAI in PICUs has been reported to be CLABSI, followed by pneumonia, and UTI [10,11]. Similarly, in our study, the most common infections were VAP and CLABSI.

UTIs have been a focus of many recent studies aimed at understanding and reducing their incidence. Rates of UTI have varied significantly across different studies, with newer reports often showing a decrease due to improved prevention strategies. This may be related to the more frequent use of diapers, and decreased use of catheters due to low median age of our patients. The prevalence of VAP was found to be relatively high because most of our patients had chronic disease [12]. Weakened immune systems in individuals with chronic illnesses pose a significant risk factor for HAIs. The prolonged hospital stays, extended treatment periods, and more frequent application of invasive procedures in these patients are the primary reasons for the increased risk of infection.

The use of invasive devices (catheters, mechanical ventilators) significantly increases the risk of infection in individuals with chronic diseases who stay for extended periods in intensive care units and hospital settings, due to their weakened defense mechanisms and the frequent use of invasive interventions [13]. The most common examples of this include VAP, UTI, and CLABSI. In our study, consistent with similar studies in the literature, it was observed that most of the cases had an underlying chronic disease. This finding once again highlights the impact of chronic conditions, particularly those that weaken the immune system, on health and their potential to increase the risk of infections. Additionally, the presence of underlying diseases is an important factor that may affect treatment processes and recovery times for patients.

Children in PICUs are at greater risk compared to adults due to issues such as vascular access problems, frequent medication administration requirements, and the need for intensive nursing care. The small size of veins and the fragility of vein walls in children can make it challenging to establish peripheral venous access. This situation often necessitates the use of invasive procedures and CVCs. However, prolonged use of CVCs can lead to serious complications, such as CLABSI [14,15]. CVC was present in 92.8% of our patients, and a urinary catheter was used in 99.2%, which contributed to a higher risk for complications. Additionally, 88.8% of our patients were monitored with mechanical ventilation, increasing the likelihood of complications such as VAP. Among HAIs, respiratory failure was the most frequent in our study spanning a 6-year period. This was followed by CLABSI, VAP, and UTIs. These results align with findings from various studies, which highlight that ventilator-associated infections and catheter-related infections are significant concerns in PICU settings.

The most commonly identified pathogens causing HAIs in PICUs in recent reports are *A. baumannii*, *Pseudomonas* spp, and *Klebsiella* spp. These pathogens are part of the ESKAPE (*Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *A. baumannii*, *Pseudomonas aeruginosa, Enterobacter* spp.) group, which are known for their high resistance to antibiotics and their prevalence in critical care settings [16]. In a study conducted in a PICU in the United States, the most common HAI was CLABSI, accounting for 41.3% of cases, followed VAP at 22.7%. The most common pathogens responsible for VAP in a recent study were *Pseudomonas* spp. *Klebsiella* spp, and *S. aureus* [17]. In our study, the most frequently identified pathogens in cases of VAP were *Pseudomonas* spp, *Klebsiella* spp, and *A. baumannii*. This pattern is consistent with the broader trends observed in critical care settings, where these bacteria are known to dominate due to their high levels of antibiotic resistance and ability to thrive in hospital environments. The prevalence of these specific

pathogens underscores the ongoing challenge of managing multidrug-resistant organisms in PICUs. In a study conducted in 50 PICUs in 27 different cities in Turkey, the most frequently isolated pathogens were *Pseudomonas* spp. *A. baumannii*, and *Candida* spp. Carbapenem susceptibility was observed in 71% of *P. aeruginosa* and *A. baumannii* strains, while colistin susceptibility was reported in 83% of the strains [18].

In our study, carbapenem resistance was observed in *Pseudomonas* spp. (25.8%), *Klebsiella* spp (9.7%), and *A. baumannii* (54.8%). These findings are in line with multiple global studies demonstrating the critical impact of device-associated infections, including CVC-associated infections, on patient outcomes in the PICU setting. The presence of invasive devices such as CVCs has been consistently associated with high mortality rates due to complications such as bloodstream infections and sepsis [19]. In our study, patients with congenital diseases had a significantly shorter median survival time (65 days) compared to those with chronic diseases (151 days). Comorbidities were identified as a significant risk factor for mortality. Cox regression analysis revealed that the risk of death in patients with congenital diseases was 3.074 times higher than in that with chronic conditions (HR = 3.074; 95% CI: 1.577–5.995). Gender was significantly related to mortality, but no significant difference in survival times was found between the genders. Additionally, 33.6% of patients died during the study period.

In a comprehensive study in which antimicrobial susceptibility was evaluated, the most frequently resistant Gram-negative pathogens were *E. coli*, *Klebsiella* spp, *Pseudomonas* spp, and *A. baumannii*. Although the rates of resistance were different in other studies, the most common pathogens were similar. In our study, the resistance rate of *E. coli* was found to be significantly lower than the previously reported rates [20,21].

Treatment of resistant Gram negative infectıons is particularly challenging for pediatricians. Antibiotics such as fluoroquinolone, colistin, and tigecycline are not used in pediatric patients; except in mandatory cases. In addition, tigecycline, which is a savior for physicians caring for adults, has not been approved for use in children. Although tigecycline use in children has been reported to be safe in a few publications in the literature, more comprehensive studies are needed [22,23]. Similarly, empiric colistin treatment should be avoided in children due to its side effects. In our study, the rate of colistin resistance was low.

Conclusions

Our study had several limitations. The sample size was limited, and it was a single-center study. Historically, PICUs are a relatively new medical field compared to other units. The patients observed in the PICU differ in characteristics from those in adult care units, adult intensive care units, and non-PICU pediatric wards. In line with this principle, our study shows that underlying chronic diseases and the presence of CVCs in patients observed in our hospital's PICU increase the risk of HAIs. The development of HAIs in children admitted to the PICU negatively impacted morbidity and mortality. Studies on PICUs and outcomes in PICUs in our country are limited compared to international literature. There is a need for more detailed studies, particularly on specific types of HAIs, in the context of our country.

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Conflict of interests

No conflict of interests is declared.

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