

Prevalence and contributing factors of nosocomial bloodstream infections in pediatric cardiac ICU patients at chamran hospital, Isfahan

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Abstract

BACKGROUND: Congenital heart disease (CHD) profoundly impacts pediatric health, leading to increased morbidity and complex care requirements, often resulting in prolonged hospital stays. Nosocomial infections, particularly bloodstream infections (BSIs), pose a significant risk in the Pediatric Cardiac Intensive Care Unit (PCICU). This study aims to evaluate the prevalence of nosocomial BSIs in children with CHD within the PCICU and to identify associated risk factors.

METHODS: A retrospective analysis was conducted on data recorded from patients under 18 years of age who had confirmed positive blood cultures and were hospitalized for a minimum of 48 hours from March 2019 to March 2022. Demographic, clinical, and microbiological information was collected, and statistical analyses were performed to determine the relationships between various risk factors and positive blood cultures.

RESULTS: In this analysis of 510 patients evaluated, positive blood cultures were found in 16.7% of patients. Patients with positive cultures were significantly younger and had lower mean weights ($P < 0.05$). Recovery status was a significant predictor of blood culture results ($p < 0.001$). Device utilization, including urinary catheters and central venous lines, was notably higher in the positive culture group ($P < 0.05$). Additionally, a higher proportion of patients with positive cultures had acyanotic CHD, with significant associations for Patent Ductus Arteriosus (PDA), Ventricular Septal Defect (VSD), and Atrial Septal Defect (ASD) ($P < 0.001$). Improved recovery status decreased the likelihood of positive blood cultures by approximately 52.2% (odds ratio 0.478, $p = 0.0021$).

CONCLUSION: Our findings reveal a high prevalence of BSIs in the PCICU, highlighting some associated risk factors such as recovery status, use of central vein catheters, dialysis and Foley catheters, younger age, and lower weight. This study emphasizes the necessity for rigorous infection control measures, particularly regarding the management of invasive devices and prompt clinical interventions, to improve patient outcomes in this high-risk population. Enhanced surveillance and tailored guidelines are essential for reducing the risks of nosocomial infections in pediatric cardiac care settings.

Keywords: Nosocomial Infections; Bloodstream Infections (Bsis); Congenital Heart Disease (CHD); Pediatric Cardiac Intensive Care

Introduction

Congenital heart disease (CHD) represents a significant public health concern and is one of the most prevalent congenital disorders affecting children today¹. The complexity of CHD presents numerous challenges, leading to high morbidity rates and intricate healthcare needs. These challenges often necessitate advanced medical interventions, such as surgeries and specialized treatments, which can result in prolonged hospital stays². While these medical advancements have markedly improved patient care, they also increase the risk of nosocomial infections, particularly in the Pediatric Cardiac Intensive Care Unit (PCICU)³.

Nosocomial infections, defined as infections acquired during hospitalization, pose a serious threat to pediatric patients. These infections can lead to extended hospital stays and elevated mortality rates⁴. Research indicates that children who develop bloodstream infections (BSIs) may experience an additional 14.6 days in the ICU and 21.1 days overall in the hospital, with a mortality rate approaching 13%⁵. Central line-associated bloodstream infections (CLABs) are especially prevalent in pediatric ICUs, placing a substantial burden on healthcare resources and families⁶. Adhering to clinical guidelines and implementing robust infection control measures can significantly reduce the incidence of these infections⁷.

The primary risk factors for nosocomial infections in pediatric cardiac patients include the use of central venous catheters, recent surgical interventions, urinary catheters, and extended hospitalizations⁸. Additionally, children with heart conditions are at an increased risk for complications such as endocarditis⁹. Understanding the pathogens involved and the associated risk factors is crucial for the effective prevention of BSIs¹⁰.

Despite extensive research on infections in neonatal and pediatric ICUs, there is limited knowledge regarding the dynamics of these infections in pediatric cardiac ICUs, particularly in Iran. A study conducted in Tehran reported a 9.3% rate of hospital-acquired infections

in neonatal and pediatric ICUs¹¹, but specific investigations focused on pediatric cardiac ICUs are scarce.

This study aims to address this gap by investigating the prevalence and risk factors associated with nosocomial BSIs in the PCICU at Chamran Hospital in Isfahan. By examining the frequency and risk factors of these infections, we hope to identify strategies to reduce infection rates and improve outcomes for children with CHD. Ultimately, the findings will contribute to the development of guidelines and strategies that can mitigate the risk of nosocomial infections within Iran's pediatric healthcare system.

Methods

This study was designed as a retrospective investigation to determine the prevalence and risk factors of nosocomial BSIs in the PCICU of Chamran Hospital in Isfahan, Iran, from March 2019 to March 2022. The focus was on infants and children under 18 years of age who had been diagnosed with CHD and had stayed in the PCICU for at least 48 hours with confirmed positive blood cultures¹². The primary goal of this study was to ascertain the frequency of positive blood cultures in the pediatric cardiac ICU. Additionally, specific factors such as age, gender, duration of hospitalization, presence of central venous catheters, and any previous surgeries or procedures were evaluated¹³.

During the hospitalization period, the patients might face one of these four categories:

1. Complete recovery and discharge
2. Partial recovery and discharge
3. Transfer to another center
4. Death

Study Population

Infants and children under 18 years of age with CHD who had been hospitalized in the pediatric cardiac ICU for at least 48 hours were included³. Patients with congenital immunodeficiency diseases and those who had received antibiotics prior to blood culture collection were not included.

We utilized the hospital's Health Information System (HIS) to identify patients who met our criteria during the two-year period, allowing for a comprehensive review of their medical records¹⁰. A total of 510 pediatric patients who were admitted to the PCICU at Chamran Hospital in Isfahan during the mentioned time period and met the criteria were selected from HIS by census.

Informed consent was obtained from all participants to protect their privacy and autonomy, and the names of participants remained confidential. Our research protocol was reviewed and approved by the Research Ethics Committee of the School of Medicine at Isfahan University of Medical Sciences (IR.MUI.MED.REC.1401.073).

Data Collection

Blood cultures were collected from patients presenting with symptoms indicative of a possible bloodstream infection, such as fever, tachycardia, alterations in general condition, and low platelet counts¹⁴. A minimum of 2 cc of blood was drawn from peripheral veins, and if necessary, from central venous catheters. These cultures were processed using the BACTEC system (including BACTEC Ped Plus/F media) to identify any microorganisms¹⁵. The identification of microorganisms was confirmed using standard microbiological techniques, and antibiotic susceptibility was assessed using the agar diffusion method¹⁰.

Our data collection consisted of a detailed checklist containing demographic information (age, gender), clinical variables (types of heart disease, surgeries performed, presence of intravenous catheters, Foley catheterization, dialysis, length of hospital stay, and any angiographic procedures), and microbial culture and sensitivity data.

Statistical Analysis

Data were entered into IBM SPSS Statistics version 25 for analysis. Descriptive statistics summarized means and standard deviations for quantitative variables and frequencies with

relative percentages for categorical variables. The prevalence of nosocomial infections was analyzed in relation to identified risk factors.

To assess the relationships between qualitative variables and positive blood cultures, the chi-square test was employed. If the data met normality conditions, independent samples t-tests were conducted for quantitative variables; otherwise, the non-parametric Mann-Whitney U test was used. Normality of data distribution was evaluated using the Kolmogorov-Smirnov test.

Logistic regression analysis was performed to determine risk factors associated with positive blood cultures while adjusting for prior antibiotic use and the patient's hospitalization history. Results were reported as odds ratios (OR) with 95% confidence intervals (CI), and a p-value of less than 0.05 was considered statistically significant.

Results

In this study, we analyzed data from 510 pediatric patients admitted to the PCICU at Chamran Hospital in Isfahan. The overall recovery rate was 84.7%, and 3.5% were transferred to other centers for further care. A total of 11.8% died. Due to the complexity of CHD, 79.8% of patients underwent surgical interventions. Positive blood cultures were reported in 85 (16.7%) of the patients. The mean (SD) hospitalization period in patients with positive blood cultures was 10.04 (7.60) days.

Characteristics of the patients with positive and negative blood cultures are presented in [Table 1](#). Patients with positive blood cultures were younger, and their mean weight was lower than those with negative blood cultures ($P < 0.05$). Patients with complete or partial recovery had a statistically significantly lower incidence of positive blood cultures (67.1%) compared to those who did not recover (88.2%) ($p < 0.001$). Patients who had undergone surgery comprised 90.6% of the positive blood culture group, compared to 77.6% of those with negative cultures ($p = 0.007$).

In terms of device utilization, in patients with

Table 1. Characteristics of the patients with congenital heart disease hospitalized in the pediatric cardiac ICU with positive and negative blood culture

Variable	Total (n=510)	Positive blood cultures (n=85)	Negative blood cultures (n=425)	P-value
Age (month)[Mean(SD)]	33.62(48.04)	13.56(24.98)	37.63(50.50)	<0.001*
Weight (gram) [Mean(SD)]	12031.02(2018.44)	7082.35(5536.96)	13020.75(12705.69)	0.014*
Gender(female/male)[n(%)]	244 (47.8)/ 266 (52.2)	39 (45.9)/46 (54.1)	205 (48.2)/220 (51.8)	0.692**
Recovery Status[n(%)]				
-Improvement	432 (84.7)	57 (67.1)	375 (88.2)	<0.001**
-Death	60 (11.8)	22 (25.9)	38 (8.9)	
-Transfer to Another Center	18 (3.5)	6 (7.1)	12 (2.8)	
Underwent Surgery[n(%)]	407 (79.8)	77 (90.6)	330 (77.6)	0.007**
Underwent Angiography[n(%)]	124 (24.3)	19 (22.4)	105 (24.7)	0.644**
Having Urinary Catheter [n(%)]	435 (85.3)	80 (94.1)	355 (83.5)	0.012**
Having dialysis Counter [n(%)]	374 (73.3)	72 (84.7)	302 (71.1)	0.009**
Having CV Line Status[n(%)]	450 (88.2)	82 (96.5)	368 (86.6)	0.01**
Congenital heart disease[n(%)]				
-A cyanotic	335 (65.7)	46 (54.1)	289 (68.0)	0.014**
-Cyanotic	175 (34.3)	39 (45.9)	136 (32.0)	
Acyanotic congenital heart disease[n(%)]				
-PDA	164 (32.4)	37 (34.9)	127 (31.8)	0.000**
-VSD	156 (30.8)	30 (28.3)	126 (31.6)	
-ASD	85 (16.8)	15 (14.2)	70 (17.5)	
-Others	100 (19.8)	24 (22.6)	76 (19.1)	
Cyanotic Congenital Disease[n(%)]				
-Tetralogy of Fallot	68 (38.8)	8 (20.5)	60 (42.6)	0.658**
-TGA	42 (24.0)	11 (28.2)	34 (24.1)	
-Pulmonary Atresia	16 (9.2)	10 (25.6)	6 (4.2)	
-Others	49 (28.0)	10 (25.6)	41 (29.1)	
Common Germs[n(%)]				
-Acinetobacter		17 (21.5)		
-Klebsiella		13 (16.5)		
-Staphylococcus Epidermidis		9 (11.4)		
-Citrobacter		7 (8.9)		
-Yeast		7 (8.9)		
-Other		26 (32.8)		
Common Antibiotics[n(%)]				
-Co-Trimoxazole		29 (16.6)		
-Ciprofloxacin		21 (12.0)		
-Gentamicin		16 (9.1)		
-Cefepime		16 (9.1)		
-Imipenem		14 (8.0)		
-Other		79 (45.1)		

* Mann-Whitney Test

**Chi-square test for qualitative variables

positive blood cultures, the rate of using urinary catheters, central venous lines, and dialysis was significantly higher than in those with negative blood cultures ($P<0.05$).

A higher proportion of patients with positive blood cultures had acyanotic CHD. Significant differences were noted in specific conditions like Patent Ductus Arteriosus (PDA), Ventricular Septal Defect (VSD), and Atrial Septal Defect (ASD) ($P<0.001$). No significant differences were found in specific conditions like Tetralogy of Fallot, Transposition of Great Arteries, and

pulmonary atresia ($P=0.658$).

The logistic regression analysis further emphasized recovery status as a significant predictor of positive blood cultures, with an OR of 0.478 ($p=0.0021$), indicating that improved recovery is associated with a decreased likelihood of detecting a nosocomial infection. This finding indicates that its odds decrease by approximately 52.2% for patients with complete or partial recovery (Table 2).

In our microbial analysis, the most common pathogens identified in patients with

Table 2. Logistic regression analysis to determine risk factors associated with positive blood cultures

Variable	Odds Ratio	95% Confidence Interval	p-value
Unadjusted analysis			
Recovery Status	0.482	0.227-1.023	0.057
Gender Status	1.05	0.467 – 2.297	0.911
Surgical Status	6.31	0.683 – 58.366	0.104
Angiography Status	0.745	0.250 - 2.221	0.597
CV Line Status	1.442	0.394-4.723	0.998
Catheter/Dialysis Status	0.542	0.114 - 2.588	0.443
Urinary Catheter Condition	0.915	0.048 - 17.444	0.953
Cyanotic or Acyanotic Status	0.309	0.128 – 0.747	0.009
Age Status (months)	1.006	0.979 - 1.034	0.654
Patient's Weight Status (grams)	1	1.000 - 1.000	0.074
Constant	0.000001	-	0.998
Adjusted for prior antibiotic use and hospitalization history			
Recovery Status	0.478	0.305 - 0.748	0.0021
Gender Status	0.92	0.556 - 1.525	0.747
Surgical Status	3.03	0.781 - 11.755	0.109
Angiography Status	1.169	0.577 - 2.365	0.665
CV Line Status	1.673	0.323 - 8.677	0.54
Catheter/Dialysis Status	1.138	0.457 - 2.836	0.781
Urinary Catheter Condition	0.902	0.187 - 4.350	0.898
Cyanotic or Acyanotic Status	0.694	0.401 - 1.202	0.192
Age Status (months)	1.008	0.991 - 1.025	0.343
Patient's Weight Status (grams)	1	1.000 - 1.000	0.187
Constant	1.399	-	0.804

bloodstream infections (BSIs) in this study were *Acinetobacter* (21.5%) and *Klebsiella* (16.5%). These pathogens are known for their resistance to multiple antibiotics, complicating treatment options and increasing the risk of adverse outcomes. Regarding antibiotic sensitivity, we found that Co-Trimoxazole, Ciprofloxacin, and Gentamicin exhibited higher sensitivity rates, reinforcing their candidacy for empirical therapy.

Discussion

In this study, we analyzed data from pediatric patients admitted to the PCICU at the referral hospital in Isfahan. Our findings indicate an overall recovery rate of 84.7%, with a notable mortality rate of 11.8%. Positive blood cultures were identified in 16.7% of the patients,

and those with positive cultures had a mean hospitalization duration of 10.04 (7.60) days. Patients with positive blood cultures tended to be younger and had a lower mean weight compared to those with negative cultures. Furthermore, recovery status was significantly associated with the incidence of positive blood cultures, highlighting a critical relationship between clinical outcomes and nosocomial infections.

Previous studies have reported varying rates of nosocomial infections in pediatric cardiac patients. The rate was reported to be 31.9% in India, 23.9% in Saudi Arabia, 5.3% in the USA, 3.2% in Tehran, Iran, and 11.9% in Mashhad, Iran¹⁶⁻²⁰.

Our finding of 16.7% suggests a consistent

prevalence of infections in this demographic. Additionally, the association of younger age and lower weight with positive blood cultures is supported by findings from previous studies, which indicated that these factors are critical risk indicators for infections in pediatric patients²¹⁻²⁴.

Our data reveal that children with BSIs often experience prolonged hospitalizations, corroborating findings from a systematic review that reported average ICU stays increased by 14.6 days, with total hospitalizations extending by 21.1 days⁵. Alarming, the mortality rate of 25.9% among our patients with positive cultures reflects similar concerns outlined by Cook et al. (2021) and Karagiannidou et al. (2020), who emphasized the severe implications of infections on pediatric outcomes^{4,5}. This underscores the urgent need for effective interventions, especially in critical care settings.

Interestingly, recovery status emerged as a robust predictor for positive cultures, suggesting that healthier children had a lower incidence of infections (odds ratio=0.478, $p=0.0021$). This finding resonates with previous research emphasizing the importance of timely clinical improvements in reducing infection risks^{25,26}.

Our analysis indicated that patients with certain common acyanotic congenital diseases, such as Patent Ductus Arteriosus (PDA) and Ventricular Septal Defect (VSD), exhibited higher rates of BSIs. In contrast, while several patients presented with common cyanotic conditions such as Tetralogy of Fallot and Transposition of the Great Arteries, no significant differences were found in infection rates between these groups. Such findings suggest that underlying pathophysiological differences may influence the susceptibility to infections in these populations and highlight the need for tailored infection control measures depending on the type of congenital heart defect.

We identified several key risk factors associated with increased rates of BSIs in our cohort. Chief among these was the use of central venous catheters (CVCs); 88.2% of our patients had CVCs, echoing findings from multiple studies that report CLABs as a significant concern in

pediatric ICUs²⁷. The necessity for stringent monitoring and infection prevention protocols is crucial, as highlighted by multiple studies showing increased incidences linked to invasive procedures^{28,29}.

While urinary catheterization was common with 85.3% of patients needing catheters the complexity of the relationship between urinary catheters and BSIs calls for vigilant monitoring and maintenance. Effective catheter management practices are essential, as highlighted by reports from Snyder et al. (2020) regarding infection risks associated with catheter use³⁰.

In our microbial analysis, the most common pathogens identified in patients with bloodstream infections (BSIs) in this study were *Acinetobacter* (21.5%) and *Klebsiella* (16.5%). These pathogens are known for their resistance to multiple antibiotics, complicating treatment options and increasing the risk of adverse outcomes. The predominance of these organisms highlights the need for robust infection control measures and antimicrobial stewardship programs in the PCICU to mitigate the risk of BSIs and improve patient outcomes.

This aligns with findings from Duan et al. that noted a rising prevalence of multidrug-resistant bacteria in healthcare settings, particularly in ICUs^{10,26}. Acknowledging these pathogens underscores the importance of ongoing surveillance and the implementation of effective antimicrobial stewardship programs.

Regarding antibiotic sensitivity, we found that Co-Trimoxazole, Ciprofloxacin, and Gentamicin exhibited higher sensitivity rates, reinforcing their candidacy for empirical therapy. This finding is particularly relevant considering the global trend of rising antibiotic resistance, as described by Romandini et al.³¹. Continuous monitoring of resistance trends is critical for adapting treatment protocols effectively.

This study is significant as it provides valuable insights into the clinical characteristics and outcomes of pediatric patients with CHD in a PCICU setting. Understanding the prevalence of positive blood cultures and their association with recovery can inform clinical practices,

improve patient management, and potentially reduce morbidity and mortality in this vulnerable population.

The significant association between recovery status and positive blood cultures emphasizes the need for monitoring infection rates in the PICU. The odds ratio of 0.478 suggests that patients who achieve complete or partial recovery are less likely to develop nosocomial infections. This finding emphasizes the need for early intervention strategies to enhance recovery and minimize infection risk. Moreover, the higher prevalence of acyanotic CHD among patients with positive cultures suggests a potential area for targeted clinical attention and research.

The significant association between recovery status and the incidence of positive blood cultures underscores the importance of implementing targeted strategies to prevent BSIs in pediatric patients. Enhanced infection control protocols, including strict adherence to hand hygiene, careful monitoring of invasive devices, and timely removal of unnecessary catheters, can significantly reduce the risk of infections. Additionally, routine screening for common pathogens, such as *Acinetobacter* and *Klebsiella*, can facilitate early identification and treatment, ultimately improving recovery rates and reducing mortality.

The strengths of this study lie in its relatively large sample size and thorough data collection from a single institution, enabling a detailed analysis of pediatric patients within a specific clinical context. However, limitations include the retrospective cross-sectional design, which may introduce biases, as well as the absence of long-term follow-up data to evaluate the enduring effects of positive blood cultures on patient outcomes. This limitation also hinders our ability to establish causal relationships, a constraint that is common in previous research. Furthermore, the findings of this study may not be generalizable to other settings due to differences in clinical practices and population demographics^{32,33}.

Future studies should adopt a multi-center

approach to enhance the generalizability of findings related to nosocomial infections in pediatric cardiac patients, thereby offering deeper insights into their long-term impacts across diverse populations. Gathering feedback from healthcare providers on current infection control practices will be crucial in identifying barriers to effective implementation, which is essential for improving pediatric cardiac care and ensuring patient safety in increasingly complex healthcare settings. Additionally, prospective study designs are recommended to accurately assess the causative factors behind positive blood cultures and their implications for long-term outcomes. Research should also focus on interventions aimed at reducing infection rates, particularly among younger patients or those with specific congenital heart defects. Furthermore, investigating the role of device utilization in infection rates could yield valuable insights, ultimately contributing to enhanced patient care and safety in this vulnerable population^{29,32}.

The findings of this study highlight the important link between recovery status and positive blood cultures in pediatric patients with congenital heart disease. They emphasize the need for vigilant monitoring and proactive management of nosocomial infections in the PICU. By addressing risk factors and optimizing the management of invasive devices, healthcare providers can enhance patient outcomes and reduce bloodstream infection rates. The study calls for further research to improve clinical practices and develop targeted guidelines to safeguard the health of vulnerable pediatric populations facing complex medical challenges.

Conclusion

Our findings reveal a high prevalence of BSIs in the PICU, highlighting some associated risk factors. This study emphasizes the necessity for rigorous infection control measures, particularly regarding the management of invasive devices and prompt clinical interventions, to improve patient outcomes in this high-risk population. Enhanced surveillance and tailored guidelines

are essential for reducing the risks of nosocomial infections in pediatric cardiac care settings.

Conflict of interests

The authors declare no conflict of interest.

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Author's Contributions

Study Conception or Design: LS, CM

Data Acquisition: MAH

Data Analysis or Interpretation: SH

Manuscript Drafting: LS, CM, MAH

Critical Manuscript Revision: MRS, AA, MG, BD

All authors have approved the final manuscript and are responsible for all aspects of the work.

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