The Incidence of Nosocomial Bloodstream Infections in Children With Congenital Heart Disease Undergoing Cardiac Surgery: A Retrospective Study

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Abstract- Congenital heart disease (CHD) is the most common congenital abnormality in children and often requires surgical intervention. These children are vulnerable to nosocomial infections (NIs), particularly bloodstream infections (BSIs), after surgery. In this study, we aimed to investigate the incidence of bloodstream infections BSIs after cardiac surgery. This retrospective study was conducted on pediatric patients refered to Children's Medical Center Hospital, affiliated with Tehran University of Medical Sciences, from March 2022 to March 2023 for cardiac surgery. The records of 449 patients were reviewed, with 436 meeting inclusion criteria. Data were extracted from medical records, including age, weight, gender, clinical diagnoses, and blood culture results. Statistical analysis was performed using descriptive statistics (including frequency, percentage, mean, and standard deviation) and inferential statistics (including Chi-square and Independent t-test) in SPSS version 23. The results showed that the incidence of BSIs in pediatric CHD patients after cardiac surgery was 3.21%. Postoperative blood cultures revealed that Klebsiella pneumoniae was the most common pathogen (42.9%), followed by Escherichia coli and Staphylococcus epidermidis (14.3% each). No significant association was found between BSIs and gender (P=0.70), weight (P=0.06), or diagnosis (P=0.44). However, age was significantly associated with BSI incidence (P<0.001). This study provides important insights into the incidence of nosocomial BSIs in pediatric CHD patients after cardiac surgery. Our results highlight the need for stronger infection control measures and targeted antibiotic therapies to effectively manage BSIs. Further research is recommended to validate these results and improve preventive measures in pediatric cardiac units.

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Introduction

Congenital heart disease (CHD) is the most common type of congenital disorder in children. The prevalence of CHD is estimated to be between 6 and 13 subjects per 1000 live births. Half of the children with CHD will require surgical intervention in their lifetime. Also, many of these children need surgery during the first year of their life (1,2). These children are highly susceptible to infections. The occurrence of infection is a critical factor that negatively influences their prognosis, rehabilitation, and recovery process following surgery (3).

Nosocomial infections (NIs) are infections that a patient acquires during their stay in a healthcare facility (4). Postoperative NIs are defined as cases of hospital-acquired infection diagnosed after surgery, with no evidence that the infection was present or incubating at the time of surgery (5). Previous studies showed that NIs are one of the major causes of bad prognosis, mortality, and prolonged hospital stay (1,6).

A study in China reported an incidence rate of 2.10% for NIs after pediatric CHD surgery (3). The results of another study in China showed that the prevalence of NIs in these children was 10.80% (7). According to a study

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conducted in Mashhad, Iran, the prevalence of NIs in children with CHD undergoing cardiac surgery was 11.96% (1).

The most common types of NIs include urinary tract infections, lower respiratory tract infections, surgical site infections, and bloodstream infections. Nosocomial bloodstream infections (BSIs) are considered more critical than other types of NIs due to their severity and impact on patient outcomes. BSIs are associated with higher mortality rates and longer hospital stays compared to other nosocomial infections (8,9).

The incidence of BSIs in pediatric intensive care units (PICUs) is higher than in other wards due to the frequent use of invasive procedures such as indwelling catheters, invasive monitoring, and utilization of central venous (CV) lines. These invasive procedures and medical equipment are an inevitable part of advanced therapeutic interventions in PICUs to save the lives of patients, but they breach the normal host defense mechanisms, making them prone to BSIs (10,11). Each of the invasive interventions can contribute to BSIs, depending on the aseptic condition, methods of care, and infection control policies in every health facility. Given the fact that many of the children with CHD underwent cardiac surgery in their first year of life, it should be noted that they are highly susceptible to BSIs due to the lack of immune system evolution (12).

The symptoms of infections in infants are usually nonspecific, and deciding to use broad-spectrum antibiotics is difficult (13). The length of hospital stays and costs for medical care are associated with the development of NIs. Also, the mortality rate in patients with NIs is significantly higher (14). A good knowledge of epidemiology and the incidence of common germs can help us make the right decisions to reduce and control BSIs. Also, a comprehensive epidemiological knowledge of responsible germs will make antibiotic prophylaxis more accurate and effective. Our literature review showed that a few studies were conducted about this issue. These studies had some limitations, such as a small number of samples and errors in data collection (1). This study aimed to assess the incidence of post-cardiac surgery BSIs.

Materials and Methods

Study design

This retrospective study was conducted on pediatric patients with CHD referred to Children's Medical Center Hospital, affiliated with Tehran University of Medical Sciences, Iran, from March 2022 to March 2023. In this study, we reviewed the medical files and records of all 449 patients who were admitted for open heart surgeries.

Setting

The admission process for patients undergoing cardiac surgery in Children's Medical Center Hospital begins with their hospitalization in Surgery Ward 2. In this ward, various preoperative tests, including blood tests, chest X-rays, echocardiograms, and other prerequisites for cardiac surgery, are conducted. Children are transferred from Surgery Ward 2 to the operating room and from there to the Open Heart Intensive Care Unit.

Inclusion and exclusion criteria

The inclusion criteria were all the admitted patients for cardiac surgery. The exclusion criteria were the presence of positive blood culture prior to the surgery, incompleted medical records, and expired patients before or during surgery.

Data collection

Data collection was carried out based on the patients' medical records. Demographic information, including age, gender, weight, and diagnosis, was recorded. The blood cultures and other laboratory test results were recorded based on the medical records.

Data analysis

Data analysis was performed using Statistical Package for the Social Sciences (SPSS) software version 23. Descriptive statistics (including frequency, percentage, mean, and standard deviation) and inferential statistics (including chi-square and independent t-test) were used to analyze and report demographic variables and clinical data.

Results

We reviewed the data of 449 patients, of which we excluded the incomplete medical information of 13 patients. The blood culture results showed that no patient had a positive culture before surgery. Therefore, the results of 436 patients were examined. Table 1 shows the demographic characteristics of the patients and their association with having a positive blood culture after surgery. The mean age of patients was 836.85±195.28 days. The mean weight of patients was 20.22±16.29 kilograms. Most of the patients were male (241, 55.28%). The most common diagnoses in patients were ventricular septal defect (111, 25.5%), atrial septal defect (84,

19.3%), and atrioventricular septal defect (39, 8.9%). The results showed that gender (P=0.70), weight (0.06), and diagnosis (0.44) had no statistically significant association with the incidence of BSIs. The results showed a statistically significant association between the age and incidence of BSIs (P<0.001).

Table 2 shows the prevalence of various microorganisms in blood cultures of patients. Of 436 patients, 14 had positive blood cultures after cardiac surgery. The incidence of postoperative BSIs was 3.21%. The most common organism found in the blood cultures was a gram-negative organism called Klebsiella pneumoniae, accounting for 42.9% of positive cultures. The next most common organisms were Escherichia coli and Staphylococcus epidermis, with an equal proportion of 14.3%. Four other gram-negative organisms, including Serratia marcescense, Pseudomonas aeruginosa, Enterobacter cloacae, and Klebsiella, all accounted for 7.1%.

Table 1. Demographic characteristics of the patients and their association with incidence of BSIs

Characteristic	Frequency (%)/Mean±SD	Positive blood culture
Age (Days)	836.85 ± 195.28	P<0.001*
Gender		
Male	241 (55.28)	P=0.70**
Female	195 (44.72)	
Weight (Kilograms)	20.22 ± 16.29	P=0.06*
Diagnosis		
ASD	84 (19.3)	
AVSD	39 (8.9)	
COA	23 (5.3)	
PDA	25 (5.7)	
PS	11 (2.5)	P=0.44**
Single ventricular	30 (6.9)	
TAPVC	14 (3.2)	
TGA	16 (3.7)	
TOF	33 (7.6)	
VSD	111 (25.5)	
Others	50 (11.5)	

ASD: Atrial septal defect; AVSD: Atrioventricular septal defect; COA: Coarctation of the Aorta; PDA: Patent ductus arteriosus; PS: Pulmonary stenosis; TAPVC: Total Anomalous Pulmonary Venous Connection; TGA: Transposition of the great vessels; TOF: Tetralogy of Fallot; VSD: Ventricular septal defect

* Independent t-test ** Chi-square

Table 2. Prevalence of microorganisms in blood cultures

Gram Positive Organism	Gram negative organism	Frequency	Percentage
	Klebsiella Pneumoniae	6	42.9%
	Escherichia Coli	2	14.3%
Staphylococcus epidermidis		2	14.3%
	Serratia Marcescens	1	7.1%
	Pseudomonas Aeruginosa	1	7.1%
	Enterobacter Cloacae	1	7.1%
	Klebsiella	1	7.1%

Discussion

The aim of this study was to assess the incidence of BSIs after cardiac surgery and the type of microbial pathogens that cause them. In this regard, we examined the medical information of 436 patients. The incidence of BSIs in children undergoing cardiac surgery was reported to be 3.21% in our study. Previous studies have reported mixed results on this topic. In a study in Shiraz, Iran, the prevalence of BSIs was 15% in pediatric wards (15). The results from a study in a children's hospital in Kenya found a prevalence rate of 21% for BSIs (16). A similar study in a children's hospital in Indonesia found an incidence rate of 2%, which is in line with our results (17). Similar to our study, the results of a study in Pakistan showed that out of 1147 children, BSIs were detected in 42 cases, showing a prevalence of 3.66% (18).

The incidence of BSIs varies between previous

studies due to several potential factors. Effective infection control practices, including adherence to hand hygiene, aseptic techniques, and appropriate use of personal protective equipment, are crucial in reducing infection rates (19,20). The frequency and management of invasive procedures, such as central line insertions, influence infection incidence, particularly when sterile techniques are not appropriately applied (21). Moreover, hospital infrastructure, staffing levels, and environmental hygiene play significant roles in infection control (22).

According to our results, Klebsiella pneumoniae was the most common organism in the positive blood cultures. Klebsiella pneumoniae is a gram-negative, encapsulated, nonmotile bacterium found in the environment. This pathogen accounts for 3 to 8% of all NIs in United States of America (23). In a study in United Arab Emirates, the results showed that in infants with early-onset sepsis, Klebsiella pneumoniae was the most common organism (24). A similar study in China showed that Klebsiella pneumoniae was the most common cause of BSIs, which is consistent with our results (25).

In our study, Escherichia coli was found to be the second most common causative agent of BSIs. Escherichia coli is a gram-negative bacillus known to be part of the normal intestinal flora, but some strains can cause NIs in humans. The urinary tract is the most common extraintestinal site of infection caused by Escherichia coli. It should be noted that the BSIs caused by Escherichia coli are often the result of a primary Escherichia coli infection elsewhere (26). Similar to our results, in a study in Taiwan, it was reported that Escherichia Coli is the most common organism causing BSIs (27). In another study in China, Escherichia coli, Staphylococcus aureus, and Klebsiella pneumoniae were the most common organisms causing BSIs, which is consistent with our results (28).

The third most common agent of BSIs in our study was found to be Staphylococcus epidermidis. This organism is a commensal bacteria found on human skin and mucous membranes, but it has emerged as a significant opportunistic pathogen. It is the most frequently isolated coagulase-negative staphylococcus and has become a major cause of implant-associated infections, leading to BSIs (29,30). Consistent with our results, in a study in Italy, the most prevalent agents of BSIs were escherichia Coli, Staphylococcus aureus, and Staphylococcus epidermidis (31). A similar study in Iran reported that Staphylococcus epidermidis was the most common microorganism causing BSIs, which is similar to our results (15).

The lack of significant correlation between gender and BSIs aligns with previous research, suggesting that gender may not be a critical determinant in infection susceptibility (32). The borderline result for weight suggests that while weight may have some influence, it was not strong enough in this study to reach statistical significance. This finding warrants further investigation, especially in larger sample sizes, to clarify the potential impact of weight on BSI risk. The significant association between age and BSI incidence underscores the vulnerability of certain age groups to infections, which could be due to age-related factors such as immune system immaturity in younger populations or immune decline in older individuals. This result is consistent with existing literature that identifies age as a key risk factor for BSIs (32,33). Targeted strategies, such as age-specific infection prevention protocols, may be necessary to mitigate the risk of BSIs in vulnerable age groups. Future studies should explore the underlying mechanisms by which age influences BSI susceptibility and investigate potential interventions tailored to different age groups.

Limitations

This study is one of the few studies conducted in Iran on BSIs after pediatric cardiac surgery. Our results provide further evidence on the frequency of BSIs and the type of pathogens that cause them. This knowledge can improve our understanding of antibiotics that could be used for treatment or prophylaxis. However, our research had several limitations. First, this study was conducted in only one center. Therefore, our results may not be generalizable to other centers. Second, the retrospective nature of this study may introduce bias, as it relies on the accuracy of medical records for data collection. It is recommended to conduct prospective studies to obtain more accurate data and to explore the association between medical procedures and patient connections with the incidence of bloodstream infections. Such studies could contribute to a more precise identification of factors influencing the risk of bloodstream infections and lead to the improvement of prevention and treatment protocols.

This study demonstrated an incidence rate of 3.21% for nosocomial bloodstream infections (BSIs) in pediatric patients with congenital heart disease (CHD) following cardiac surgery. Klebsiella pneumoniae emerged as the most prevalent pathogen, followed by Escherichia coli and Staphylococcus epidermidis. The results showed that while gender, weight, and diagnosis were not significantly associated with BSIs, age was a key factor contributing to increased susceptibility. These findings emphasize the critical need for targeted infection control

strategies, particularly focusing on younger patients who are more vulnerable. Given the severity of BSIs and their impact on patient outcomes, it is critical to improve infection control practices, particularly regarding invasive procedures, and optimize antibiotic prophylaxis to prevent these infections. Further multicenter studies are recommended to validate these findings and enhance infection prevention strategies across various healthcare settings.

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References

1. Alizadeh B, Dolatkhah G, Akhavan H, Birjandi H, Sistani MRN, Shahri HMM. Microbiology of Post-Cardiac Surgery Infections in Children with Congenital Heart Diseases, A Single-Center Experience, Mashhad, Iran. Arch Pediatr Infect Dis 2022;10.
2. Orchard J, Suna J, Renner A, Gordon L, McCarthy L, Pool N, et al. Wound management across Australian and New Zealand pediatric cardiac services: a cross-sectional survey. Cardiol Young 2024;34:1432-8.
3. Wang X, Li S, Huo D, Zhu Z, Wang W, He H, et al. Nosocomial Infections After Pediatric Congenital Heart Disease Surgery: Data from National Center for Cardiovascular Diseases in China. Infect Drug Resist 2024;17:1615-23.
4. Arpan S, Kalyan R, Mainak C, Karunakaran G. Correlation between Antimicrobial Resistance and Nosocomial Infections, their Prevention and Control. J Young Pharm 2020;12:25.
5. Kajiyazdi M, Dasdar S, Kianfar N, Kaveh M. Nosocomial Infection Surveillance in Neonatal Intensive Care Units of Bahrami Children's Hospital. Arch Pediatr Infect Dis 2021;9:e108840.
6. Jia H, Li L, Li W, Hou T, Ma H, Yang Y, et al. Impact of Healthcare-Associated Infections on Length of Stay: A Study in 68 Hospitals in China. Biomed Res Int 2019;2019:2590563.
7. Yu X, Chen M, Liu X, Chen Y, Hao Z, Zhang H, et al. Risk factors of nosocomial infection after cardiac surgery in children with congenital heart disease. BMC Infect Dis 2020;20:64.
8. Bychinin MV, Antonov IO, Klypa TV, Mandel IA, Minets AI, Kolyshkina NA, Golobokova YB. Nosocomial infection in patients with severe and critical COVID-19. Gen Reanimatol 2022;18:4-10.
9. Li L, Huang H. Risk factors of mortality in bloodstream infections caused by Klebsiella pneumonia: A single-center retrospective study in China. Medicine (Baltimore) 2017;96:e7924.
10. Almazeedi MA, Al Ghadeer HA, Bugshan AS, Alhrthi HL, Alshuaibi MK, Albarqi HH, et al. Pattern and Frequency of Nosocomial Infections in the Pediatric Intensive Care Unit at East Jeddah General Hospital, Saudi Arabia. Cureus 2023;15:e47561.
11. Bennett EE, VanBuren J, Holubkov R, Bratton SL. Presence of invasive devices and risks of healthcare-associated infections and sepsis. J Pediatr Intensive Care 2018;7:188-95.
12. Shariat M, Youssefkhani AB, Dalili H, Hajinasab N, Farrokhzad N, Nozarian Z, et al. Associated Factors and Common Pathogens of Positive Cultures in Infants With Definitive Septicemia Admitted to NICU. Acta Med Iran 2023;61:355-60.
13. Ting JY, Autmizguine J, Dunn MS, Choudhury J, Blackburn J, Gupta-Bhatnagar S, et al. Practice summary of antimicrobial therapy for commonly encountered conditions in the neonatal intensive care unit: a Canadian perspective. Front Pediatr 2022;10:894005.
14. Gidey K, Gidey MT, Hailu BY, Gebreamlak ZB, Niriayo YL. Clinical and economic burden of healthcare-associated infections: A prospective cohort study. Plos one 2023;18:e0282141.
15. Dashti AS, Kadivar MR, Tabatabai A, Zand F, Salami S, Ezadpanah S, et al. Prevalence of Healthcare-Associated Infections in Pediatric Wards of Nemazee Teaching Hospital in Shiraz: A Comparison with the Whole Hospital. Arch Pediatr Inf Dis 2019;7:e83488.
16. Patil RK, Kabera B, Muia CK, Ale BM. Hospital acquired infections in a private paediatric hospital in Kenya: a retrospective cross-sectional study. Pan Afr Med J. 2022;41:28.
17. Murni IK, Duke T, Kinney S, Daley AJ, Wirawan MT, Soenarto Y. Risk factors for healthcare-associated infection among children in a low-and middle-income country. BMC Infect Dis 2022;22:406.
18. Mustafa ZU, Khan AH, Salman M, Harun SN, Meyer JC, Godman B, et al. Healthcare-associated infections among neonates and children in Pakistan: findings and the implications from a point prevalence survey. J Hosp Infect 2023;141:142-51.
19. Ramakrishnan K, Venugopal J, Easow JM, Ravishankar M. Incidence, bacteriological profile and antibiotic resistance pattern of catheter associated urinary tract infections in a tertiary care hospital. J Pure Appl Microbiol

2019;13:1549-54.
20. Kubde D, Badge AK, Ugemuge S, Shahu S. Importance of Hospital Infection Control. Cureus 2023;15:e50931.
21. Buetti N, Marschall J, Drees M, Fakih MG, Hadaway L, Maragakis LL, et al. Strategies to prevent central line-associated bloodstream infections in acute-care hospitals: 2022 Update. Infect Control Hosp Epidemiol 2022;43:553-69.
22. Subbalakshmi E. Surveillance of Hospital Acquired Infection from Frequently Handled Surfaces in a Tertiary Care Teaching Hospital. Int J Curr Microbiol App Sci 2018;7:860-6.
23. Ashurst JV, Dawson A. Klebsiella Pneumonia. StatPearls. Treasure Island (FL): StatPearls Publishing Copyright © 2024, StatPearls Publishing LLC.; 2024.
24. Elhalik M, Habibullah J, El-Atawi K. Epidemiology of sepsis in NICU; A 12 years study from Dubai. J Pediatr Neonatal Care 2018;8:84-8.
25. Lyu ZY, Zhen JH, Meng QY, Zhou W, An JY, Dong F. Bacterial Etiology and Antimicrobial Resistance Pattern of Pediatric Bloodstream Infections in Beijing, 2015–2019. Infect Drug Resist 2023;16:6297-308.
26. Mueller M, Tainter CR. Escherichia coli Infection. StatPearls. Treasure Island (FL): StatPearls Publishing Copyright © 2024, StatPearls Publishing LLC.; 2024.
27. Liao WC, Chung WS, Lo YC, Shih WH, Chou CH, Chen CY, et al. Changing epidemiology and prognosis of nosocomial bloodstream infection: A single-center retrospective study in Taiwan. J Microbiol Immunol Infect 2022;55:1293-300.
28. Tian L, Sun Z, Zhang Z. Antimicrobial resistance of pathogens causing nosocomial bloodstream infection in Hubei Province, China, from 2014 to 2016: a multicenter retrospective study. BMC Public Health 2018;18:1-8.
29. Severn MM, Horswill AR. Staphylococcus epidermidis and its dual lifestyle in skin health and infection. Nat Rev Microbiol 2023;21:97-111.
30. Skovdal SM, Jørgensen NP, Meyer RL. JMM profile: Staphylococcus epidermidis. J Med Microbiol 2022;71:001597.
31. Luzzaro F, Ortisi G, Larosa M, Drago M, Brigante G, Gesu G. Prevalence and epidemiology of microbial pathogens causing bloodstream infections: results of the OASIS multicenter study. Diagn Microbiol Infect Dis 2011;69:363-9.
32. Seni J, Mwakyoma AA, Mashuda F, Marando R, Ahmed M, DeVinney R, et al. Deciphering risk factors for blood stream infections, bacteria species and antimicrobial resistance profiles among children under five years of age in North-Western Tanzania: a multicentre study in a cascade of referral health care system. BMC Pediatr 2019;19:32.
33. Mohamed AA, Haftu H, Hadgu A, Seyoum D, Gebrekidan G, Ebrahim MM, et al. Prevalence, Clinical Profile and Risk Factors of Nosocomial Infection in Ayder Pediatric Intensive Care Unit, Tigray, Ethiopia. Int J Gen Med 2022;15:7145-53.