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RESEARCH ARTICLE

Catheter-associated Bacteremias in Neonates and Infants Following Congenital Cardiac Surgery: A Single-center Experience

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ABSTRACT

Objectives: Congenital heart diseases (CHD) are among the most common reasons for intensive care unit (ICU) admission in neonates and infants. Catheter-associated bacteremias (CAB) can lead to increased morbidity and mortality in these patients. This study aimed to investigate the incidence of CAB and the risk factors influencing its development in neonates and infants undergoing congenital heart surgery.

Methods: This retrospective study included patients younger than 12 months who underwent congenital heart surgery and were monitored in a pediatric cardiac intensive care unit between January 1, 2022, and January 1, 2025. The type, location, duration of catheterization, and associated complications were recorded. Demographic data, clinical characteristics, and outcomes were summarized on a per-patient basis. Each case was matched with two control patients based on age and date of surgery. The results were analyzed statistically.

Results: During the study period, congenital heart surgery was performed in 1,200 patients under the age of 12 months. Catheter-associated bacteremia was detected in 32 cases (2.6%). Among the isolated bacterial agents, 84% were gram-negative organisms and 16% were gram-positive organisms. Independent risk factors associated with CAB were: RACHS-1 ≥ 4 (OR 1.2, 95% CI 1–1.5), central venous catheter (CVC) duration > 10 days (OR 1.9, 95% CI 1.2–5), ECMO support (OR 0.8, 95% CI 0.6–2), and delayed sternal closure ≥ 2 days (OR 0.6, 95% CI 0.4–2). The mortality rate due to catheter-associated bacteremia was 18.7%, which was 5.8 times higher compared to the control group.

Conclusion: Catheter-associated bacteremias are a significant cause of morbidity and mortality in neonates and infants undergoing congenital heart surgery, and the majority are caused by gram-negative microorganisms.

Keywords: Catheter-associated bloodstream infection, congenital heart surgery, pediatric cardiac intensive care unit

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Introduction

Congenital heart disease (CHD) comprises a group of malformations of varying complexity, with over 300 possible diagnoses and a range of palliative or definitive surgical interventions. These conditions significantly impact morbidity, mortality, and quality of life. Children with CHD may have a distinct risk profile for infections. Pediatric cardiac surgery patients are often neonates or small infants who undergo major surgical procedures and are exposed to the inflammatory and immunosuppressive effects of cardiopulmonary bypass. Additionally, the perioperative period is frequently characterized by the use of multiple invasive devices.[1,2]

The role of transthoracic monitoring lines is well established in patients undergoing corrective or palliative procedures for congenital or acquired heart diseases. These lines are routinely used in many centers, in conjunction with CVCs placed in the neck or femoral vein. Moreover, additional

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CVCs are increasingly utilized for access, particularly in neonates with complex intraoperative courses, prolonged postoperative recovery, single-ventricle physiology undergoing palliative surgery, or those undergoing cardiac transplantation requiring extended operative times. Central venous catheters may also be necessary for medication infusion, hemodialysis, and parenteral nutrition.[3,4]

Catheter-associated bacteremias (CAB) are a major cause of morbidity and mortality in pediatric cardiac intensive care units. Higher infection rates have been reported with non-antibiotic-coated catheters, multi-lumen catheters, administration of blood transfusions, parenteral nutrition, certain catheter insertion sites and durations, the presence of a gastrostomy tube, and underlying cardiac diagnoses. Additionally, catheter-associated thrombosis has been implicated as a contributing factor to CAB development.[2–5]

There are limited published data on the incidence of CAB in children with congenital heart disease undergoing cardiac surgery. However, it is known that this critically ill population is predisposed to immunodeficiency and disruption of natural barriers to infection. Furthermore, patients undergoing non-elective procedures appear to be at greater risk for developing CAB.[4]

This study aims to determine the frequency of CAB in patients under 12 months of age undergoing cardiac surgery in a pediatric cardiac intensive care unit and to evaluate potential risk factors associated with CAB.

Methods

The study was conducted as a retrospective case-control study on cases under the age of 1 year who were admitted to the pediatric cardiac intensive care unit between January 1, 2022, and January 1, 2025. Our unit is a Level 3 heart center with a capacity of 39 beds, where all congenital heart diseases, except for heart transplants, are monitored and treated.

Patients were divided into two groups: the CAB group and the control group. Our patients' blood cultures for the first 14 days postoperatively were retrospectively reviewed. Microbial growth within the first 2 days after CVC placement was not considered clinically significant, as it was not associated with the central catheter, following previous literature. Patients with microbial growth in blood cultures between days 3 and 14, along with their antibiotic susceptibility test results, were recorded. If the blood culture from CVC was positive, the CVC was removed and sent for culture analysis. We established the diagnosis of CAB in our patients when the following criteria were met: (a) clinical findings correlated, (b) a recognized pathogen was cultured from blood cultures between days 3 and 14, (c) signs were unrelated to an infection at another site, (d) inflammatory blood biomarkers were increased in the laboratory, and (e) a recognized pathogen was cultured from the tip of the catheters.[6] The isolated pathogens were recorded. We defined bacteremia as the isolation of bacterial species from at least 1 blood culture. If multiple episodes of bacteremia occurred in the same patient during the study period, only the first episode was considered for the study. Control patients were admitted to the same pediatric cardiac intensive care unit (PCICU) as case patients, in the same period (range of up to ±30 days) and with the same age range (±10%) but did not develop bacteremia.[7] Two matched control patients were recruited for each case patient.

The study was planned in accordance with the Helsinki Declaration after obtaining approval from the local committee.

Upon admission to the operating room, electrocardiography, noninvasive blood pressure, pulse oximetry, and near-infrared spectroscopy monitoring were performed, and induction drugs were administered. All cases were planned to be extubated in the shortest time possible. In perioperative anesthesia management, the appropriate medications were administered within the framework of the protocol used in the clinic where this study was conducted. According to this protocol, in children aged six months, 0.1 mg/kg midazolam, 1 µg/kg fentanyl, and 0.6 mg/kg rocuronium were administered at induction; and 0.1 µg/kg/minute remifentanil, 5 µg/kg/minute rocuronium, and a minimum of 1–1.2 alveolar concentration sevoflurane were administered for maintenance. In children older than six months, 0.1 mg/kg midazolam, 1 µg/kg fentanyl, and 0.6 mg/kg rocuronium were administered at induction; and 0.25 µg/kg/minute remifentanil, 5 µg/kg/minute rocuronium, a minimum of 1–1.2 alveolar concentration sevoflurane, and 0.5 µg/kg/hour dexmedetomidine were administered for maintenance. The effects of neuromuscular agents were antagonized by sugammadex. Remifentanil and rocuronium were discontinued after the sternum was closed. Sevoflurane was discontinued before the skin was closed. Dexmedetomidine was continued until the patient was transferred to the pediatric cardiac intensive care unit.[8]

After the intubation process, CVC and arterial cannulas were placed by anesthesiologists experienced in pediatric cardiac anesthesia. CVC placement was performed according to the recommendations of the Centers for Disease Control and Prevention, with maximum sterile barrier precautions. The practitioner applied surgical hand

antisepsis procedures, wore a mask, cap, sterile gloves, and gown, and a large sterile drape was used in the field. After swabbing the entry sites twice with 10% povidone-iodine solution, they were allowed to dry. All neonates were administered a 4 Fr 5 cm double-lumen catheter, and the procedure was routinely performed under ultrasound guidance. The choice of catheter localization was made according to the preference of the practitioner. The intensive care dressings for catheters were changed every 2 days or when deemed necessary. Catheter or dressing materials containing self-antiseptics were not used.[6]

A five-component hand hygiene practice is routinely implemented in our unit (CVC insertion and care protocol, solution preparation protocol, unit/patient surface hygiene and cleaning protocol, introduction of a liaison nurse, discussion during handoffs about the need to continue or not with CVC in each patient in the unit).

A data collection form was created for each case. This form included preoperative data (demographic characteristics, preoperative clinical status, cardiac diagnosis, echocardiographic findings, and the presence of syndromes); intraoperative data (use of cardiopulmonary bypass [CPB], duration of surgery, and Risk Adjustment for Congenital Heart Surgery 1 [RACHS-1] score); and postoperative data (length of stay in the intensive care unit and hospital, mortality, presence of a central venous catheter (CVC) for more than 48 hours, and any complications that occurred).

Catheter-related bacteremia was defined according to the Infectious Disease Society of America guidelines.[9] Crude mortality, defined as the rate of death within 30 days of bacteremia, was assessed.[10] The following primary measures were estimated to establish the impact of the program: rate of CVC-related bacteremias/1000 days of CVC use, rate of CVC use/100 patient days, standardized infection ratio (SIR) according to the surveillance definition by the Centers for Disease Control and Prevention (CDC).[9,11]

Bacterial colonies were identified using matrix-assisted laser desorption/ionization-time-of-flight (MALDI-TOF) Microflex LT/SH Smart MS (Bruker Daltonics, Germany) and the MALDI-Biotyper Compass IVD 4.2.90 database. Antibacterial susceptibility testing of bacterial strains isolated from blood samples was performed using Sensitised YeastOne (SYO) kits (Thermo Fisher Diagnostics, The Netherlands) according to the manufacturer's guidelines. Minimum inhibitory concentration (MIC) values were determined after 24 hours of incubation based on the CLSI M27-A4 and M60-2nd edition standards.

This study was conducted in compliance with the Declaration of Helsinki and was approved by the University of Health Sciences Türkiye, Basaksehir Çam and Sakura City Hospital Ethics Committee (Approval Number: KAEK/23.10.2024.22).

Statistical Analysis

The data were analyzed using SPSS Statistics 21. The demographic data were presented as the number, percentage, and median (interquartile range, IQR). Categorical variables between the bacteremia and control groups were compared using the chi-square or Fisher's exact test. Continuous variables were compared using the Mann–Whitney U test. Multivariable logistic regression was used to examine the in-depth associations between the groups and potential variables to identify potential independent predictors. p values of<0.05 were considered statistically significant.

Results

During the study period, a total of 1,200 cardiac operations were performed. The incidence of bacteremia was 21.8 episodes per 1,000 cardiac PICU admissions. The total length of patient stay was 6,900 patient-days, with 4,100 catheter-days, resulting in a catheter utilization rate of 59%. The rate of CVC-related bacteremias was 7.8 per 1,000 catheter-days. The expected number of bacteremia episodes was 45, and the standardized infection ratio (SIR) was calculated as 0.71.

A total of 96 patients, including 32 bacteremia cases and 64 matched controls, were included in the study. The median age of patients with bacteremia was 2 months (IQR 1–3). Fifty percent of the cases were male.

Bacteremia developed a median of 9 days (IQR 6–12) after surgery. Bacteremia species were detected in the blood cultures of 32 out of 1,200 patients (2.6%). Klebsiella pneumoniae (n=12, 37.5%), Enterobacter cloacae (n=5, 15.6%), Pseudomonas species (n=3, 9.3%), Escherichia coli (n=3, 9.3%), Enterococcus faecium (n=3, 9.3%), methicillin-resistant coagulase-negative Staphylococci (n=2, 6.2%), Acinetobacter species (n=2, 6.2%), Stenotrophomonas maltophilia (n=1, 3.1%), and Citrobacter species (n=1, 3.1%) were isolated.

Factors associated with the development of bacteremia in the cardiac PICU were first analyzed by univariable analysis (Table 1). Subsequent multivariable logistic regression analysis identified the risk factors (Table 2) that remained independently associated with CAB: RACHS-1 score≥4 (OR=1.2, 95% CI: 1.0–1.5), duration of central venous catheterization>10 days (OR=1.9, 95% CI: 1.2–5.0), requirement for ECMO support (OR=0.8, 95% CI: 0.6–2.0), and delayed sternal closure≥2 days (OR=0.6, 95% CI: 0.4–2).

The 30-day crude mortality rate for bacteremia was 18.7% (6/32).

Table 1. Demographic and clinical variables for patients with catheter-associated bacteremias patients and control patients

Variables	CAB (n=32)		Control (n=64)		p
	n	%	n	%	
Background ilness	8	25	7	11	NS
Age,months	2 (1–3)		2 (1–3)		NS
Weight,kg	3.9 (3.5–5)		4 (3.6–4.5)		NS
Birth weight (kg)					NS
≥2.5	29 (91)		60 (84)		
<2.5	3 (9)		4 (6)		
Male	16	50	32	50	NS
Genetic syndrome	3	9	5	7.8	NS
Single ventricle physiology	12	37.5	25	40	NS
Cyanotic heart disease	16	50	34	53	NS
Duration of preoperative mechanical ventilation (days)	2 (0–4)		1 (0–2)		NS
CPB use	29	91	60	94	NS
CPB time (min)	90 (80–100)		85 (75–95)		NS
RACHS-1 ≥4	20	62	16	25	**<0.001**
Localization of CVC					NS
Femoral vein	19	59.4	37	57.8	
Jugular vein	10	31.3	22	34.3	
Umblical vein	3	9.3	5	7.8	
Central venous catheter duration (days)	12 (8–16)		5 (3–10)		**<0.001**
Transfusion	29	91	32	50	**0.002**
TPN	16	50	8	12.5	**<0.001**
Duration of TPN (days)	10 (6–14)		2 (1–3)		**<0.001**
ECMO	6	18.8	2	3.1	**<0.001**
Arrhythmias	3	10	7	11	NS
Acute Kidney Injury	5	15	7	11	NS
LCOS	7	21	10	16	NS
Chylothorax	2	6.2	2	3.1	NS
Delayed sternal closure ≥2 days	9	28	2	3.1	**<0.001**
Previous antibiotic use	4	12.5	7	11	NS
ICU stay (days)	18 (15–21)		8 (6–10)		**<0.001**
Post-op hospital stay (days)	30 (25–36)		14 (12–16)		**<0.001**
Mortality	6	18.7	2	3.2	**<0.001**

Median (IQR); n (%). CAB: Catheter-associated bacteremias; CPB: Cardiopulmonary bypass; RACHS-1: Risk adjustment for congenital heart surgery; CVC: Central venous catheter; TPN: Total parenteral nutrition; ECMO: Extracorporeal membrane oxygenation; LCOS: Low cardiac output syndrome; ICU: Intensive care unit; NS: Non-significant.

Discussion

In this study, we investigated the incidence of catheter-associated bacteremia (CAB) and the contributing risk factors in neonates and infants who underwent congenital heart surgery. The incidence of CAB was found to be 2.6%. The majority of CAB cases were caused by gram-negative microorganisms. Independent risk factors associated with CAB included a RACHS-1 score≥4, duration of central venous catheterization>10 days, requirement for ECMO support, and delayed sternal closure≥2 days. Mortality was observed to be 5.8 times higher in the CAB group compared

Table 2. Multivariate logistic regression analysis of factors associated with the development of catheter-associated bacteremias

Variables	p	OR	95% CI
RACHS-1 ≥4	0.01	1.2	1–1.5
ECMO	0.005	0.8	0.6–2
Central venous catheter duration ≥10 days	<0.001	1.9	1.2–5
Delayed sternal closure ≥2 days	0.02	0.6	0.4–2

OR: Odds ratio; CI: Confidence interval; RACHS-1: Risk adjustment for congenital heart surgery; ECMO: Extracorporeal membrane oxygenation.

to the control group. With these characteristics, our study is among the limited number of studies in the literature addressing CAB in this specific patient population.

Hospital-acquired infections remain a major concern across all healthcare settings; however, their consequences may be particularly severe in resource-limited environments of the developing world. Due to budget constraints, the higher cost of care for infected survivors may limit access to surgery for other patients with congenital heart disease. Bloodstream infections are among the most common nosocomial complications, especially in intensive care units. While surgical intervention itself is a risk factor, the use of CVCs in children has been reported to increase the risk of catheter-associated bloodstream infections (CABSI) by approximately 1.0%–3.9%.[12] In a study by Abou Elella et al.[13] this rate was found to be 8.6%. A more recent study reported the incidence of CABSI as 1.5% in neonates and 0.8% in infants.[4] In our study, the incidence of CAB was found to be 2.6%. This variation may be attributed to differences in diagnostic criteria used.

Neonates and infants are at high risk for numerous medical complications. Patients diagnosed with critical congenital heart disease are at an even greater risk due to early invasive procedures and prolonged hospital stays. Reducing potential complications is key to improving adverse outcomes. Defining the incidence of CAB in this population helps promote advancements in catheter care and usage, as well as facilitates the evaluation of current CAB prevention practices and their outcomes. Ruvinsky et al.[11] evaluated cases of CAB in a pediatric cardiac intensive care unit between 2008 and 2018. They reported that, through the implementation of a catheter care program, the bacteremia rate decreased from 11.9 per 1,000 catheter-days in 2008–2009 to 3.8 per 1,000 catheter-days by 2018.

The National Nosocomial Infections Surveillance System (NNIS) surveyed 161,314 patients from 54 general pediatric intensive care units (PICUs) in the United States and reported a mean CABSI rate of 6.6 per 1,000 central line days.[14] In our study, this rate was found to be 7.8 per 1,000 catheter-days.

The spectrum of microorganisms causing CABSI in our PCICU differs from those reported by the NNIS.[14] Gram-negative organisms predominated in 84% of our patients, whereas the NNIS identified gram-positive microorganisms, particularly coagulase-negative Staphylococci, as the primary etiology of CABSI.[14] Other investigators from specialized PCICUs and some general pediatric ICUs have reported findings essentially consistent with ours.[13,15]

Various independent risk factors have been reported for CABSI. In one study, lower patient weight, higher surgical complexity score, open sternum postoperatively, and longer duration of central line use were identified as independent risk factors.[13] Costello et al.[16] reported independent risk factors including operative weight less than 5 kg, Pediatric Risk of Mortality (PRISM) III score greater than 15, receipt of more than three units of blood products, and mechanical ventilation for more than 7 days. In our study, independent risk factors were RACHS-1 score ≥4, central venous catheter duration >10 days, ECMO support, and delayed sternal closure ≥2 days.

The mortality rate was higher among patients with CAB. Haughey et al.[4] reported higher mortality in infected neonates (17.8% vs. 9.7%) and infants (16.6% vs. 1.9%) compared to controls. In a study including 317 cases, mortality was found to be 5.5 times higher in infected patients compared to controls (11% vs. 2%).[13] In our study, mortality was 18.7% in infected patients and 3.2% in those without infection.

Limitations

The main limitations of this study include its retrospective design, single-center setting, and relatively small sample size. The heterogeneity of patient pathologies, differing physiological outcomes, and inclusion of only bacteremia cases also constitute limitations.

Conclusion

Catheter-Associated Bacteremias are a significant cause of morbidity and mortality in neonates and infants undergoing congenital heart surgery. It is predominantly caused by gram-negative organisms. Efforts should be focused on correcting preventable factors to reduce its incidence.

Disclosures

Ethics Committee Approval: The study was approved by the University of Health Sciences Türkiye, Basaksehir Çam and Sakura City Hospital Ethics Committee (no: 23.10.2024.22, date: 07/11/2024).

Informed Consent: Not applicable due to the retrospective nature of the study.

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