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RESEARCH ARTICLE

# Nozocomial Infections in Patients Under 1 Year of Age Hospitalized in Pediatric Cardiology and Cardiovascular Surgery Intensive Care Unit

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**ABSTRACT**

**Objective:** In the field of pediatric cardiology and cardiovascular surgery intensive care units (PCICU), especially neonates and infants are at higher risk for nosocomial infections. We wanted to present the infections, we encountered during the follow-up of patients in our PCICU.

**Materials and Methods:** Patients <1 year of age who were hospitalized in the PCICU between January 01, 2022, and January 01, 2023, who required treatment, clinical infections, and agents that had an effect on clinical outcome were retrospectively analyzed. Bloodstream infection, clinical sepsis, pneumonia, surgical site infection, and intra-abdominal infection cases were included in the study.

**Results:** A total of 1032 patients were followed up in the PCICU between 2022 and 2023 and 598 (58%) of them were under 1 year of age. Active infection was detected in 104/598 (17.3%) of these patients. In the assessment of patient culture samples, microbial growth was identified in 83/104 (79.8%) instances within blood cultures, 47 (45%) patients in tracheal aspirate cultures, and 12 patients (11.5%) exhibited growth in sternal swab cultures, with a notable representation of Gram-negative pathogens within all this groups. Bloodstream infections were encountered more in cases with youthful age, open sternotomy, surgical complexity, prolonged duration of central venous catheter, and extended stays within the intensive care unit.

**Conclusion:** In addition to providing care for neonates and infants with compromised immune systems, PCICUs face heightened challenges due to the increased utilization of IV catheters, leaving the sternum open after complex cardiac surgeries, and prolonged intensive care stay introduces an elevated susceptibility to infections.

**Keywords:** Infant, infection, pediatric cardiology and cardiovascular surgery intensive care units

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## INTRODUCTION

In the field of pediatric cardiology and cardiovascular surgery intensive care units (PCICU), both pre-operative and post-operative infections give rise to significant morbidity and, in some cases, even mortality within the critical care setting. It increases costs by prolonging the duration of intensive care unit stay, mechanical ventilation time, and hospitalization.[1,2] In studies conducted on pediatric patients over the last decade, infection rates have ranged from 16% to 31%.[3] The prevailing types of infections in the PCICU predominantly encompass bloodstream infections, pneumonia, and mediastinitis.[2,4]

This article aims to delineate the infections identified during the hospitalization within the intensive care unit, focusing on patients under our clinic's surveillance over a span of 1 year.

## MATERIALS and METHODS

### PCICU Setting

Our medical facility functions as a specialized heart hospital, catering primarily to cardiac patients, while other units are dedicated to providing polyclinic services.

Our hospital's PCICU comprises an 18-bed intensive care unit and a 12-bed intermediate care unit. Patient care is over-

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seen by a team including a pediatric cardiologist, two pediatric cardiology fellow, and pediatric cardiovascular surgery team. Roughly 1000 patients are typically under annual observation in our care. Admissions originate not only from Istanbul, but also from health-care facilities in other provinces across the country.

### Patient Population

Between January 01, 2022, and January 01, 2023, patients <1 year of age who were hospitalized in the PCICU of our hospital and who had an effect on the clinical course requiring treatment were retrospectively analyzed in terms of clinical infections and agents. Informed written consent was obtained from all patients' legal guardians. Pre-operative or post-operative data were recorded.

On hospitalization in the intensive care unit, patients underwent blood culture sampling, with a minimum of two samples obtained during their initial admission. In addition, tracheal aspirate cultures were collected in instances where mechanical ventilation was administered. The study encompassed cases of bloodstream infections, clinical sepsis, pneumonia, surgical site infections, and intra-abdominal infections.

Bacteremia was defined as isolation from blood cultures of one or more recognized pathogens that are not common skin flora, or isolation of organisms that are common skin flora, together with clinical signs or symptoms of infection, from (1) two or more separate blood cultures, (2) one blood culture and another site, or (3) one blood culture in a patient with an intravascular device where there is resolution of clinical signs and symptoms after removal of the device or after appropriate therapy.

The definition of sepsis in cases of concurrent bacteremia was made according to proposed criteria encompass a range of clinical indicators, including general condition disturbances, tachypnea, tachycardia, malnutrition, fever or hypothermia, impaired consciousness, elevated lactate levels, and cytopenia.

Diagnosis of necrotizing enterocolitis (NEC) was performed by combining clinical assessments of septic symptoms with clinical and radiological evidence of intestinal involvement.

Demographic data, including age, gender, diagnosis of congenital heart disease, risk adjustment for congenital heart surgery (RACHS) score, length of hospital stay before the procedure, presence of double or single ventricle, type of intervention (palliation or complete correction), infection duration, administered antibiotics along with their duration, inpatient or outpatient presentation, intubation or extubation status in the intensive care unit, clinical condition, post-operative sternal status (open or closed), duration of central venous catheter (CVC) indwelling time, and history of recurrent surgery were meticulously documented. Patients over the age of 18 years were not included in the study. Patients displaying pre-operative fever and clinical indicators of infection were deferred from surgery, even in cases where infection markers tested negative, unless cardiac surgery was urgent, and this group of patients was excluded from the study.

In general, CVCs are placed by pediatric anesthesiologists in the operating room after skin preparation with chlorhexidine, following strict aseptic rules. Nonetheless, individuals transferred directly to the intensive care unit from another facility, particularly newborns, were subjected to the insertion of an umbilical catheter following thorough sterilization protocols. For older infants, CVC was introduced under the same stringent sterilization measures. Patients with poor general condition and unstable hemodynamics were followed up by umbilical or central artery catheterization.

CVCs were positioned within the jugular, femoral, or subclavian veins. However, in cases involving patients within the single ventricle group, the femoral vein was favored due to the anticipation of future Glenn operations. Antibiotic prophylaxis was provided using cefazolin when sternal closure was conducted, while teicoplanin and cefepime were employed when the sternum remained open. The cefazolin prophylaxis regimen spanned 48 h, whereas teicoplanin and cefepime were administered until sternal closure occurred.

The occurrence of post-operative infection was defined by the Center for Disease Control criteria revised in 2008 by Horan et al.[5] The diagnosis of pneumonia was assessed based on findings from chest radiography, tracheal aspirate cultures, infection markers, and clinical indicators.

Patients with delayed sternal closure were subject to continuous monitoring through routine blood cultures and cultures from sternal wound sites, along with dedicated surveillance efforts. Swab cultures were collected during each sternal revision. Priority was given to prompt sternal closure, and in instances of suspected infection, the vacuum-assisted closure treatment technique was implemented. Patients with open sternum were followed up intubated.

Superficial wound infection is defined as bacteremia or infection limited to the skin and soft tissue above the sternum with or without positive culture from the surgical incision site; deep wound infection is defined as infection extending to the sternum and/or mediastinum.

Patients exhibiting positive blood cultures were promptly addressed through antibiotic intervention and expedited CVC removal, or alternatively, the replacement of the CVC catheter if its continued necessity was established.

Procedures are grouped according to RACHS-1 categories (Table 1). Coagulase-negative staphylococci were attributed to bacteremia only under specific conditions; when the patient displayed clinical and laboratory indications of sepsis, in the absence of any alternative source of infection, and if sustained growth was evident in consecutive cultures.

### Statistical Analysis

Analysis for categorical variables was performed using Chi-square or Fisher's exact tests, and for quantitative variables, Mann-Whitney U-tests were used. Continuous data are presented as median with ranges and as number of patients (%) for categorical variables. Comparison of continuous variables was performed with Wilcoxon and Mann–Whitney U-tests. Statistical significance was set at $p<0.05$. Data were analyzed with SPSS software version 17.0 (SPSS, Inc, an IBM Company, Chicago, IL).

## RESULTS

Throughout the period spanning 2022 to 2023, a collective sum of 1032 patients received monitoring within the PCICU. Among them, 598 individuals (58%) were infants under the age of 1 year. Among this subgroup, active infections were identified in 104 out of 598 patients (17.3%).

Median age 92 (2–360) days, median weight 4.3 (2.3–12) kg. 66/104 (63.4%) of the patients were male and 38/104 (36.5%) were female. 42/104 (40.3%) patients were admitted intubated from an external center, 20/104 (19.3%) patients were extubated from an external center, 39/104 (37.5%) patients were transferred from the ward to the operating room, 2 (1.94%) patient was transferred from the ward to the intensive care unit due to respiratory distress, and 1/104 (0.96%) patient was transferred from an external medical center while having tracheostomies in place (Table 2).

Among the observed patients, 7/104 (6.74%) individuals underwent post-angioplasty monitoring within the intensive care unit, 1/104 (0.96%) patient followed up for cardiac rhythm abnormalities and the remaining 96/104 (92.3%) patients had undergone surgical procedures. When the RACHS scores of the cases were analyzed, 19/96 (19.7%) were scored as Category 2, 45/96 (46.8%) as Category 3, 27/96 (28.1%) as Category 4, and 5/96 (5.2%) as Category 6.

Among the patient cohort, 26 out of 103 (25.2%) cases were attributed to single ventricle conditions, while the remaining 77 out of 103 (74.8%) were classified as double ventricle cases. It is important to note that the evaluation encompassed 103 patients, accounting for one patient who presented with arrhythmia.

The median duration of pre-operative hospital stay was 6.3 (1–41) days. In terms of the conducted procedures, palliative surgeries were carried out in 40 instances, while complete corrective surgeries were performed in 60 cases. Among these, six patients underwent initial palliative surgery followed by subsequent full correction procedures within the same hospitalization period. Tracheostomy was performed in 19/104 (18.2%) cases.

Sites of the hospital-acquired infections are summarized in Table 3. On analyzing patient culture samples, growth was observed in blood cultures of 83 out of 104 cases (79.8%). Among these, klebsiella pneumonia was identified in isolation in 32 cases, while *Klebsiella oxytoca* was detected in six cases. Other infectious agents detected in the study were *Serratia marcescens* in 10 cases, *Acinetobacter baumanni* in seven cases, *Candida albicans* in 13 patients, *Stenotrophomonas maltophilia* in eight cases, Methicillin-resistant coagulase-negative staphylococci in seven cases, *Pseudomonas aeruginosa* in 10 cases, *Escherichia coli* in five cases, Enterobacter faecium in four cases, *Enterococcus feacalis* in five, and *Enterobacter* (others) in patients. Nosocomial bloodstream infectious agents are also shown in Table 4.

6/104 (5.7%) cases were evaluated as sepsis due to bloodstream infection.

The median duration of CVC indwelling time was 22 (3–120) days.

Tracheal aspirate cultures showed significant and clinically compatible growth in 47/104 (45%) cases. The growth of tracheal aspirate cultures was *A. baumanni* in 10 cases, *P. aeruginosa* in 13 cases, *C. albicans* in two cases, klebsiella pneumonia in 19 cases, S. maltophilia in 10 cases, and *S. marcescens* in four cases. Of the 47 patients with growth in tracheal aspirate culture, 17/47 (36%) were tracheostomized.

There were 12/104 (11.5%) cases with growth in sternal swab culture. Two cases had klebsiella pneumonia, one case had *P. aeruginosa*, one case had *P. aeruginosa* after klebsiella pneumonia, three cases had *A. baumanni*, four cases had *C. albicans*, and one case had *E. coli* and *E. faecium*. In fiv of these cases, growth was also detected in simultaneous blood cultures. Three cases had growth in sternal swab culture simultaneously with tracheal aspirate culture, and three cases had simultaneous growth of the same agent in sternal swab culture, tracheal aspirate culture, and blood culture.

**Table 1. RACHS-1 category**

| Category 1 | Category 2 | Category 3 |
|---|---|---|
| • Atrial septal defect surgery (including atrial septal defect secundum, sinus venosus atrial septal defect, and patent foramen ovale closure)<br>• Aortopexy<br>• Patent ductus arteriosus surgery at age >30<br>• Coarctation repair at age >30 d<br>• Partially anomalous pulmonary venous connection surgery | • Aortic valvotomy or valvuloplasty at age >30 d<br>• Subaortic stenosis resection<br>• Pulmonary valvotomy or valvuloplasty<br>• Pulmonary valve replacement<br>• Right ventricular infundibulectomy<br>• Pulmonary outflow tract augmentation<br>• Repair of coronary artery fistula<br>• Atrial septal defect and ventricular septal defect repair<br>• Atrial septal defect primum repair<br>• Ventricular septal defect repair<br>• Ventricular septal defect closure and pulmonary valvotomy or infundibular resection<br>• Ventricular septal defect closure and pulmonary artery band removal<br>• Repair of unspecified septal defect<br>• Total repair of tetralogy of Fallot<br>• Repair of total anomalous pulmonary veins at age >30 d<br>• Glenn shunt<br>• Vascular ring surgery<br>• Repair of aorta-pulmonary window<br>• Coarctation repair at age ≤30 d<br>• Repair of pulmonary artery stenosis<br>• Transection of pulmonary artery<br>• Common atrium closure<br>• Left ventricular to right atrial shunt repair | • Aortic valve replacement<br>• Ross procedure<br>• Left ventricular outflow tract patch<br>• Ventriculomyotomy<br>• Aortoplasty<br>• Mitral valvotomy or valvuloplasty<br>• Mitral valve replacement<br>• Valvectomy of tricuspid valve<br>• Tricuspid valvotomy or valvuloplasty<br>• Tricuspid valve replacement<br>• Tricuspid valve repositioning for Ebstein anomaly at age >30 d<br>• Repair of anomalous coronary artery without intrapulmonary tunnel<br>• Repair of anomalous coronary artery with intrapulmonary tunnel<br>• Closure of semilunar valve, aortic or pulmonary<br>• Right ventricular to pulmonary artery conduit<br>• Left ventricular to pulmonary artery conduit<br>• Repair of double-outlet right ventricle with or without repair of right ventricular obstruction<br>• Fontan procedure<br>• Repair of transitional or complete atrioventricular canal with or without valve replacement<br>• Pulmonary artery banding<br>• Repair of tetralogy of Fallot with pulmonary atresia<br>• Repair of cor triatriatum<br>• Systemic to pulmonary artery shunt<br>• Atrial switch operation<br>• Arterial switch operation<br>• Reimplantation of anomalous pulmonary artery<br>• Annuloplasty<br>• Repair of coarctation and ventricular septal defect closure<br>• Excision of intracardiac tumor |
| **Category 4** | **Category 5** | **Category 6** |
| • Aortic valvotomy or valvuloplasty at age ≤30 d<br>• Konno procedure | | |

**Tablo 1. Cont.**

| Category 4 | Category 5 | Category 6 |
|---|---|---|
| • Repair of complex anomaly (single ventricle) by ventricular septal defect enlargement<br>• Repair of total anomalous pulmonary veins at age ≤30 d<br>• Atrial septectomy<br>• Repair of transposition, ventricular septal defect, and subpulmonary stenosis (Rastelli)<br>• Atrial switch operation with ventricular septal defect closure<br>• Atrial switch operation with repair of subpulmonary stenosis<br>• Arterial switch operation with pulmonary artery band removal<br>• Arterial switch operation with ventricular septal defect closure<br>• Arterial switch operation with repair of subpulmonary stenosis<br>• Repair of truncus arteriosus<br>• Repair of hypoplastic or interrupted arch without ventricular septal defect closure<br>• Repair of hypoplastic or interrupted aortic arch with ventricular septal defect closure<br>• Transverse arch graft<br>• Unifocalization for tetralogy of Fallot and pulmonary atresia<br>• Double switch | • Tricuspid valve repositioning for neonatal Ebstein anomaly at age≤30 d<br>• Repair of truncus arteriosus and interrupted arch | • Stage 1 repair of hypoplastic left heart syndrome (Norwood operation)<br>• Stage 1 repair of non-hypoplastic left heart syndrome conditions<br>• Damus-Kaye-Stansel procedure |

RACHS-1: Risk adjustment for congenital heart surgery

Following surgery, the sternum remained open in 48 out of 96 operated cases, accounting for 50% of the total. Among 48 patients with open sternum, 7/48 (14.5%) had growth in swab culture. Two cases had klebsiella pneumonia, one case had klebsiella pneumonia + *P. aeruginosa*, two cases had *C. albicans*, and two cases had *A. baumanni*.

The median duration for which infectious agent cultures remained positive was 7.2 (1–35) days, while the duration of antibiotic administration spanned 15 (1–60) days.

The median length of intensive care unit stay was 34.6 (2–305) days and the median length of hospitalization was 44.8 (3–365) days.

Bloodstream infections were encountered more in cases with youthful age, open sternotomy, surgical complexity, prolonged duration of CVC, and extended stays within the intensive care units (Table 5). While the rate of growth in tracheal aspirate cultures did not attain statistical significance, it was notably higher among patients with tracheostomy and external intubation. There was no difference in terms of bloodstream infection or mediastinitis in terms of complete correction or palliation. Duration of antibiotic use was significantly higher in cases with open sternum.

Nineteen patients experienced mortality within the intensive care unit. The causes of death were categorized as follows: General cardiac problems in 9 out of 19 cases (47.6%), pure sepsis in 1 case (5.2%), NEC, and sepsis in 2 cases (10.5%), NEC-related general morbidity in 1 case (5.2%), prolonged general morbidity in the intensive care unit in 2 cases (10.5%), death due to the amalgamation of infection and cardiac deterioration in 2 cases (10.5%), and fatalities attributed to adult respiratory distress syndrome and pulmonary hypertensive crisis in 2 cases (10.5%).

**Table 2. Patient characteristics**

| | n | % | Median (range) |
|---|---|---|---|
| Number of cases under 1 year of age with infection | 104/598 | 17.3 | |
| Age (day) | | | 92 (2–360) |
| Gender | | | |
| Female | 38/104 | 36.5 | |
| Male | 66/104 | 63.4 | |
| Weight (kg) | | | 4.3 (2.3–12) |
| Place of transfer | | | |
| External center/intubated | 42/104 | 40.3 | |
| External center/extubated | 20/104 | 19.3 | |
| From ward to operation room | 39/104 | 37.5 | |
| From the ward to the intensive care unit | 2 | 1.94 | |
| External medical center/tracheostomized | 1 | 0.96 | |
| Number of patients with tracheostomy | 19/104 | 18.2 | |
| Patient group | | | |
| Surgery | 96/104 | 92.3 | |
| After cardiac catheterization | 7/104 | 6.7 | |
| Arrhythmia patient | 1/104 | 1 | |
| RACHS score | | | |
| 1 | 0 | 0 | |
| 2 | 19/96 | 19.7 | |
| 3 | 45/96 | 46.8 | |
| 4 | 27/96 | 28.1 | |
| 5 | 0 | 0 | |
| 6 | 5/96 | 5.2 | |
| Cardiac pathology | | | |
| Double ventricle | 77/103 | 75 | |
| Single ventricle | 26/103 | 25 | |
| The operation performed | | | |
| Palliation | 40/103 | 38.8 | |
| Correction surgery | 60/103 | 58.2 | |
| Correction surgery following palliation | 6/103 | 5.8 | |
| Preoperative hospital stay (days) | | | 6.3 (1–41) |
| Number of patients with open sternum | 48/96 | 50 | |
| Intensive care hospital stay (days) | | | 34.6 (2–305) |
| Length of hospital stay (days) | | | 44.8 (3–365) |
| Number of patients with mortality | 19/104 | 18.2 | |
| General cardiac problem | 9/19 | 47.6 | |
| Sepsis | 1/19 | 5.2 | |
| NEC, sepsis | 2/19 | 10.5 | |
| NEC and general morbidity | 1/19 | 5.2 | |
| Long intensive care stay and general morbidity | 2/19 | 10.5 | |
| Sepsis on cardiac hemodynamic deterioration | 2/19 | 10.5 | |
| ARDS, PH crisis | 2/19 | 10.5 | |

NEC: Necrotizing enterocolitis; ARDS: Adult respiratory distress syndrome; PH: Pulmonary hypertension

Table 3. Sites of nosocomial infection

| | n | % | Median (range) |
|---|---|---|---|
| Bloodstream infection | 83/104 | 79.8 | |
| Pneumonia | 47/104 | 45 | |
| Surgical wound infection | 12/104 | 11.5 | |
| Duration of infectious agent cultures remained positive (days) | | | 7.2 (1–35) |
| Duration of antibiotic administration (days) | | | 15 (1–60) |

## DISCUSSION

Newborns and young infants are recognized to possess an underdeveloped immune system, potentially rendering them more susceptible to elevated infection rates within this demographic. Prolonged hospitalization in the intensive care unit is usually associated with prolonged mechanical ventilation and increased use of intravascular catheters.

In earlier times, the majority of pediatric patients undergoing cardiac surgery were monitored within general pediatric intensive care units (PICUs). However, the current practice entails these patients receiving dedicated monitoring and treatment within specialized PCICUs.

The inpatient population in the tertiary PCICU is thought to be different from the patient population in neonatal or general PICUs in children's hospitals.

While the infection rates were reported as 12.9% and 15.8% in the studies conducted by Dagan[6] and Pollock et al.[7] respectively, our study revealed a slightly higher rate of 17.3%. This variance could be attributed to factors including the relatively young age of the patients, the presence of underlying complex cardiac conditions rendering them susceptible to infections, and the substantial number of patients transferred for intubated or extubated from external facilities, given our status as a Level 3 pediatric cardiac surgery center. In addition, the extensive use of invasive medical devices within PCICU, the significant proportion of newborns undergoing complex cardiac surgeries, and the high patient volume might contribute to the observed elevated infection rate.

Furthermore, the higher prevalence of infection in our investigation, as compared to certain other studies, could be attributed, at least in part, to variations in nursing resources. Notably, the patient-to-nurse ratio in the study by Pollock et al.[7] was 1:1, whereas within our clinic, the patient-to-nurse ratio was 2:1.

Documented risk factors for patients undergoing hospitalization within PCICU encompass a range of variables. These include prolonged pre-operative stays within the intensive care unit, younger age at the time of surgery, complexity of cardiac surgery, duration of the surgical intervention, nasal colonization by Staphylococcus aureus, deferred sternal closure,[8] usage of invasive monitoring devices, and length of stay both in the PCICU and the hospital.[8–10] In addition, prematurity, inadequate nutrition, presence of cyanotic lesions, duration of the surgical procedure, multiple surgical interventions, frequency of blood transfusions, duration of indwelling CVC, and duration of total parenteral nutrition have been highlighted as additional reported risk factors.[2,11–13]

Table 4. Spectrum of bacterial pathogens causing hospital-acquired bloodstream infections

| Bacterial pathogens | n |
|---|---|
| *Klebsiella pneumoniae* | 32 |
| *Klebsiella oxytoca* | 6 |
| *Acinetobacter baumanni* | 7 |
| *Candida albicans* | 13 |
| *Stenotrophomonas maltophilia* | 8 |
| *Serratia marcescens* | 10 |
| *MRCNS* | 7 |
| *Pseudomonas aeruginosa* | 10 |
| *Escherichia coli* | 5 |
| *Enterobacter faecium* | 4 |
| *Enterococcus feacalis* | 5 |
| *Enterobacter (others)* | 6 |

MRCNS: Methicillin–resistant coagulase–negative staphylococci

Barker et al.,[10] utilizing the STS Congenital Heart Surgery Database, identified young age and the degree of surgical complexity as the foremost risk factors. In our investigation, a similar trend emerged, with the complexity level of the surgery notably influencing both the duration of stay in the intensive care unit and infection rates.

Although prior studies[3,4] have indicated that the duration of pre-operative hospitalization can serve as a risk factor for

Table 5. Risk factors for hospital-acquired infection

| | Those with nosocomial infections n=104 | | Those without nosocomial infections n=494 | | p | OR | %95 CI |
|---|---|---|---|---|---|---|---|
| | n | % | n | % | | | |
| Age (days) | 92 (2–360) | | 122 (22–362) | | <0.002 | 5.72 | 3.2–10.5 |
| Open chest | 48/104 | 46.1 | 20/494 | 0.40 | <0.004 | 4.2 | 2.3–7.5 |
| CVC indwelling time (days) | 22 (3–120) | | 8 (2–10) | | <0.001 | 4.5 | 1.8–9.6 |
| PCICU stay (days) | 34.6 (2–305) | | 6 (2–12) | | <0.0004 | 6 | 2.2–15.6 |
| RACHS scoring | | | | | | | |
| 1 | 0 | | 80 | | 0.0001 | 0.25 | 0.13–0.40 |
| 2 | 19 | | 202 | | 0.002 | 0.18 | 0.25–0.82 |
| 3 | 45 | | 160 | | 0.0003 | 0.22 | 0.32–0.64 |
| 4 | 27 | | 52 | | 0.42 | 0.68 | 1.12–8 |
| 5 | 0 | | 0 | | | | |
| 6 | 5 | | 0 | | 0.0001 | 3.02 | 1.27–7.5 |
| Gender (male) | 66/104 | 63.4 | 292/494 | 59 | 0.7 | 1.22 | 0.73–3.2 |
| Weight | 4.3 (2.3–12) | | 4.6 (3.2–10.8) | | 0.4 | 1.9 | 0.6–6 |
| Place of transfer (external center/intubated) | 42/104 | 40.3 | 24/494 | 4.8 | 0.07 | 2.1 | 0.8–4.96 |
| Preoperative hospital stay (days) | 6.3 (1–41) | | 4.2 (1–12) | | 0.08 | 1.3 | 0.29–6.3 |
| Length of hospital stay (days) | 44.8 (3–365) | | 36.8 (2–48) | | 0.1 | 1.2 | 0.5–2.8 |
| Cardiac pathology (single ventricle) | 26/103 | 25 | 158/494 | 32 | 0.4 | 1.5 | 0.7–3.2 |
| The operation performed (palliation) | 40/103 | 38.8 | 227/494 | 46 | 0.3 | 2 | 0.82–4.8 |
| Number of patients with tracheostomy | 19/104 | 18.2 | 2/494 | 0.4 | 0.08 | 5.3 | 0.6–47.7 |

OR: Odds ratio; CI: Confidence interval; CVC: Central venous catheter; PCICU: Pediatric cardiology and cardiovascular surgery intensive care unit; RACHS: Risk adjustment for congenital heart surgery

post-operative infections, our study did not yield a statistically significant difference in this regard.

Levy et al.[2] demonstrated a correlation between the risk of infection and higher RACHS scores in their investigation, a trend that our study also upheld. Specifically, we found an elevated risk of bloodstream infection among individuals with a RACHS score >2.

Our study predominantly identified bloodstream infections, with a noteworthy predominance of Gram-negative agents. While certain studies[14] have reported a prevalence of Gram-positive infectious agents, our findings contrasted by highlighting a dominance of Gram-negative agents. However, Gram-negative agents were also prevalent in the study conducted by Levy et al.[2] The observed discrepancy in our study could potentially be attributed to our practice of obtaining a minimum of 2 blood cultures and considering colonization when different agents grow without clinical compatibility. In addition, routine nasal and rectal swab cultures are collected from all patients during the pre-operative phase. It is noteworthy that in Candida infections, while antibiogram sensitivity is generally high, we have encountered extended periods of culture-negative results in our clinic.

The advantages of maintaining an open sternum post-pediatric cardiac surgery have been widely documented.[15,16] This approach is particularly beneficial to prevent cardiac compression, a concern amplified in younger infants due to myocardial edema and limited intrathoracic space. Furthermore, suboptimal hemodynamic indicators, primary pulmonary issues, arrhythmias, and insufficient hemostasis might hinder immediate sternal closure following open-heart surgery. The necessity for intubation in patients with an open sternum leads to extended periods of mechanical ventilation, prolonged stays in the intensive care unit and the hospital, consequently raising healthcare expenses. Nonetheless, it is worth noting that the open sternum group is primarily comprised of younger patients who have undergone complex cardiac procedures, marked by heightened morbidity and mortality.

In a study conducted by Das et al.[8] investigating the connection between delayed sternal closure and bloodstream infections in patients with hypoplastic left heart syndrome, it was observed that patients with delayed sternal closure faced a 4-fold increase in the risk of developing bloodstream infections. Their study highlighted Gram-negative agents as the primary causative agents of infection.[8] Given the inclusion of a relatively small age group and a cohort with elevated surgical complexity in our study, we observed comparable outcomes, aligning with their findings.

In the review conducted by Dresbach et al.,[17] the duration of CVC indwelling time emerged as an independent risk factor for bloodstream infection. Similarly, the study conducted by García et al.[18] identified both the duration of CVC stay exceeding 14 days and mechanical ventilation duration surpassing 7 days as general risk factors. Our study's findings aligned with these studies, indicating a similar trend, as the duration of CVC use was notably longer among individuals with nosocomial infections compared to those without.

While the utilization of CVCs is sometimes indispensable for patients undergoing complex pediatric cardiac surgeries characterized by prolonged bypass durations, substantial post-operative bleeding, or other hemodynamic challenges, it is important to acknowledge that there remains a potential risk of developing bloodstream infections despite these circumstances.

Recognizing that signs and symptoms of bacteremia, particularly in newborn infants, frequently manifest as subtle and nonspecific, a heightened level of suspicion becomes essential. This context underscores the rationale behind our adoption of a high rate of prophylactic antibiotic initiation. Therefore, knowledge of nosocomial infection agents is very important in terms of prophylactic antibiotic initiation.

Numerous studies have provided evidence that factors such as an excessive patient load, inadequate staffing, and an imbalance between workload and available resources serve as significant determinants of nosocomial infections.[19,20]

While certain factors such as surgical complexity, patient age, open sternotomy, or the presence of cyanotic congenital heart disease remain unmodifiable, it is crucial to acknowledge that nosocomial infections can be mitigated by targeting preventable elements. Swift removal of CVCs, judicious use of urinary catheters, prompt extubation from mechanical ventilation, and shortening the duration of preoperative hospitalization are among the key strategies to curtail nosocomial infections.

### Limitation of the Study

This study is a retrospectively designed within a single center and encompassed a highly heterogeneous patient group. The limited time frame further characterizes its scope. Notably a variety of other potential risk factors, such as perioperative glucose levels, duration of parenteral nutrition, and the extent of blood transfusions, were not immediately accessible and thus are not subjected to analysis. In addition, the study did not include a dedicated examination of neonates as a distinct subgroup.

## CONCLUSION

In addition to providing care for neonates and infants with compromised immune systems, PCICUs face heightened challenges due to the increased utilization of IV catheters, leaving the sternum open after complex cardiac surgeries, necessity for intubation in patients with an open sternum, and prolonged intensive care stay introduces an elevated susceptibility to infections.

### Disclosures

**Ethics Committee Approval:** The study was approved by the Istanbul Mehmet Akif Ersoy Thoracic and Cardiovascular Surgery Training and Research Hospital Clinical Research Ethics Committee (No: 2023.06-65, Date: 22/08/2023).

**Informed Consent:** Written informed consent was obtained from all patients.

**Peer-review:** Externally peer reviewed.

**Conflict of Interest:** No conflict of interest was declared by the authors.

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