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Research Article

Evaluation of Healthcare-associated Nosocomial Infections in the Pediatric Cardiovascular Surgery Intensive Care Unit in Türkiye (2012–2021)

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ABSTRACT

Objectives: The study evaluated the 10-year healthcare-associated infections (HCAI) data in the pediatric cardiovascular surgery intensive care unit (PCVS-ICU).

Methods: The electronic data of 106 patients with HCAI between 2012 and 2021 were retrospectively analyzed for the infection sites, isolated microorganisms, and antibiotic resistance.

Results: 3617 patients with 29155 patient days in our 12-bedded PCVS-ICU were evaluated. There were 64 HCAIs during 2012–2016, comprised of 17 (26.5%) bloodstream infections (BSI), 16 (25%) pneumonia, 13 (20.3%) urinary tract infections (UTI), 8 (12.5%) ventilator-associated pneumonia (VAP), 7 (11.1%) surgical site infection (SSI), and 3 (4.6%) soft-tissue infection (STI). In contrast, 42 HCAIs were observed in 2017–2021, which included 17 (40.4%) BSI, 10 (23.8%) pneumonia, 7 (16.6%) VIP, 4 (9.6%) UTI, 3 (7.2%) SSI, and 1 (2.4%) STI. The most common pathogen was the ***Candida*** species. The ventilator usage rate was 2.8 per 8635 ventilator days and 0.42 per 6439 ventilator days in the first and second five years, respectively. The rate of central venous catheter (CVC) use was 2.04 and 0.96 in the first and second five years, respectively.

Conclusion: The most common HCAI was BSI, and the most common isolated pathogen was ***Candida*** species within ten years in our PCVS-ICU. The infection rate, CVC, and UC usage rates were decreased, with an increased compliance rate on hand hygiene in the second five years, indicating strict adherence to infection control measures.

Keywords: Cardiovascular surgery, healthcare-associated infections, pediatric intensive care

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Introduction

Healthcare-associated infection (HCAI) is a significant cause of morbidity and mortality in hospitalized children. It is also responsible for prolonged hospital stays and increased costs.[1] The incidence of HCAIs varies significantly between countries, regions, and hospitals, which are associated with the causal microorganisms in the hospital, the healthcare team, and a variety of interactions among patients themselves.[2] As innate and acquired immunity are suppressed, and natural physical defenses such as skin integrity, cough reflex, and gastric motility are impaired, the susceptibility to HCAIs increases in pediatric intensive care unit patients.[3] The most common nosocomial infection in pediatric intensive care units is bloodstream infections (BSI), followed by pneumonia and urinary tract infections (UTI).[4,5]

The major HCAI pathogens in neonatal intensive care units comprised Gram-negative bacteria (GNB) such as *Klebsiella pneumonia* and *Escherichia coli*, Gram-positive bacteria such as *Staphylococcus aureus* and Coagulase-negative staphylococci (CNS).[6]

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HCAI rates in pediatric intensive care units (PICUs) in Türkiye ranged from 2.9% to 43.9%.[7] Due to the limited information available for HCAIs in the PCVS-ICU, we analyzed 10-year data on the frequency, infection sites, microorganisms grown in cultures, and antibiotic resistance registered in the hospital infection control surveillance system.

Methods

This study retrospectively analyzed the electronic data of 117 patients with HCAI in the PCV-ICU of the Kartal Koşuyolu Research and Training Hospital, Türkiye, from 2012 to 2021, according to the criteria of the Centers for Disease Control and Prevention (CDC), 2015 and the National Nosocomial Infections Surveillance Network (UHESA), 2017.

The following definitions and formulas were used to calculate healthcare-associated infection rates:

The number of hospitalized days refers to the total number of days of all patients hospitalized in the PICU during a year.

Invasive device day is the total number of days of exposure of a PICU patient to an invasive device during a year.

Healthcare-associated infection rate: Number of healthcare-associated infections/number of hospitalized patients)×100

Healthcare-associated infection frequency density (incidence): Number of healthcare-associated infections / patient days)×1000

Invasive device usage rate: Number of invasive device days/Patient days

Invasive device-related healthcare-associated infection rate (per 1000 catheter-days): (Invasive device-related SBIs/Invasive device days)×1000

Invasive device-associated healthcare-associated infection rate (%) (per 100 patients): Number of FNAIS/ Number of inpatients×100

Culture on blood, urine, sputum, wound site, and endotracheal aspirate was conducted weekly in the patients receiving catheter and ventilator therapy to exclude the infection. We transported the samples immediately after collection to the microbiology laboratory using special transport bags. Then the samples were cultivated onto the sheep blood agar, chocolate agar, and eosin methylene blue agar. The plates were incubated for 24–48 hours at 35°C±2°C. Additionally, gram staining was performed for all samples. Antibiotic susceptibility test results were evaluated according to the recommendations of the Clinical and Laboratory Standards Institute (CLSI-2015) and the European Committee on Antimicrobial Susceptibility Testing in 2018–2019. Vitek II (BioMerieux, France) system was used for the species identification of isolates in the clinical microbiology culture laboratory.

The study was approved by the ethical committee of Kartal Koşuyolu Research and Training Hospital.

Results

This study assessed 3617 patients with 29155 patient days, between 2012–2021, in 12-bedded PCVS-ICU. Of 64 HCAIs, including 17 (26.5%) BSI, 16 (25.0%) pneumonia, 13 (20.3%) UTI, 8 (12.5%) VAP, 7 (11.1%) SSI, and 3 (4.6%) STI, were detected during 2012–2016. Besides, 42 HCAIs were detected during 2017–2021, including 17 (40.4%) BSI, 10 (23.8%) pneumonia, 7 (16.6%) VIP, 4 (9.6%) UTI, 3 (7.2%) SSI, and 1 (2.4%) STI (Table 1).

The rate of HAI and incidence rate in the first five years were 3.47% and 4.54, respectively, vs. 2.26% and 2.65 in the second five years, respectively. In the first five years, the ventilator usage rate was 2.8 per 8635 ventilator days vs. 0.42 per 6439 ventilator days in the second five years.

Similarly, the CVC rate was 2.04 with a CVC use rate of 0.96 in the first five years vs. 1.8 CVC rate and 0.62 CVC use rate in the second five years. Moreover, the urinary catheter rate and the urinary catheter use rate were 0.8 and 0.91 in the first five years, vs. 0.73 ad 0.94 in the second five years, respectively.

The identified microorganisms in the first five years were *Candida albicans* (n=24), *Klebsiella pneumonia* (n=20), which were ESBL resistance (71%) and carbapenem resistance (50%), *Acinetobacter baummanii* (n=9) which showed carbapenem resistance (100%), *Pseudomonas aeruginous* (n=9) which showed carbapenem resistance (100%), and coagulase-negative staphylococci (n=5). No isolates showed colistin resistance.

In the second five years, the most common isolated pathogens were *Candida albicans* (n=41), *Klebsiella pneumonia* (n=21) which were ESBL resistance (65%), carbapenem resistance (75%), and colistin resistance (60%), *Stenomonas maltophilia* (n=20), *Acinetobacter baummanii* (n=7) which were carbapenem resistance (50%), colistin resistance (70%), *Pseudomonas aeruginosa* (n=7) which showed carbapenem resistance (100%), colistin resistance (100%) and coagulase-negative staphylococci (n=2) (Table 2).

Regarding antibiotic resistance, colistin resistance was not observed in GNB within the first five years, but it increased markedly in the second five years. Similarly, as for the carbapenem resistance, pan-resistant strains increased in the second five years. Meanwhile, hand hygiene compliance rates of the health care provider increased steadily from 77% to 86% from 2012 to 2017 and 83% to 94% from 2018 to 2021 (Table 3).

Discussion

HCAI is an important indicator of healthcare quality in developed and developing countries. Children are at higher risk

Table 1. Distribution of healthcare-associated infection (HAI) types (2012–2021)

Types of HAIs	Years																					
	2012		2013		2014		2015		2016		2017		2018		2019		2020		2021		Total	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
BSI	7	36.8	5	20	1	14.2	1	20	3	37.5	9	64.2	1	16.7	1	20	1	20	7	50	36	33.3
Pneumonia	6	31.5	6	24	2	28.4	1	20	1	12.5	0	0	2	33.3	1	20	2	40	5	35.7	26	24
VAP	4	21	2	8	2	28.4	0	0	0	0	5	35.8	0	0	1	20	1	20	0	0	15	13.8
SSTI	0	0	2	8	1	14.2	0	0	1	12.5	0	0	0	0	1	20	0	0	0	0	5	4.6
UTI	2	10.5	5	20	1	14.2	2	40	3	37.5	0	0	2	33.3	1	20	1	20	0	0	17	16
SSI	0	0	5	20	0	0	1	20	0	0	0	0	1	16.7	0	0	0	0	2	14.3	9	8.3
Total	19		25		7		5		8		14		6		5		5		14		108	

BSI: blood stream infection; VAP: ventilator-associated pneumonia; SSTI: skin and soft-tissue infection; UTI: urinary tract infection; SSI: surgical site infection.

Table 2. Distribution of the pathogens antibiotic susceptibility patterns between 2012 and 2021

Pathogens of HAIs	2012		2013		2014		2015		2016		2017		2018		2019		2020		2021	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
Total (n=194)	19		20		20		14		16		20		24		25		24		12	
Klebsiella pneumoniae (n=41)	4	21	5	25	6	30	0	0	5	31.2	4	25	2	8.3	7	28	5	20.8	3	25
Pseudomonas aeruginosa (n=23)	6	31	4	20	3	15	3	21.4	0	0	1	5	3	12.5	1	4	2	8.3	0	0
Acinetobacter baumanii (n=16)	3	15.7	2	10	3	15	0	0	1	6.2	2	10	2	8.3	0	0	3	12.5	0	0
Candida spp (n=41)	2	10.5	3	15	1	5	3	21.4	7	43.7	5	20	4	16.6	7	28	9	37.5	0	0
Candida albicans (n=24)	4	21	4	20	3	15	1	7.1	1	6.2	0	0	3	12.5	2	8	1	4.1	5	41.6
CoNS (n=7)	0	0	1	5	2	10	2	14.2	2	12.4	0	0	0	0	0	0	0	0	0	0
Escherichia coli (n=5)	0	0	2	10	0	0	2	14.2	0	0	0	0	0	0	0	0	0	0	1	8.3
Enterococcus faecium (n=6)	0	0	0	0	0	0	0	0	0	0	0	0	3	12.5	3	12	0	0	0	0
Enterococcus faecalis (n=2)	0	0	0	0	0	0	0	0	0	0	1	5	0	0	1	4	0	0	0	0
Enterobacter cloacae (n=2)	0	0	0	0	1	5	0	0	1	6.2	0	0	0	0	0	0	0	0	0	0
Stenotrophomonas maltophilia (n=23)	0	0	0	0	1	5	2	14.2	0	0	7	35	6	25	0	0	4	16.6	3	25
Serratia marcesens (n=5)	0	0	0	0	0	0	1	7.1	0	0	0	0	1	4.1	3	12	0	0	0	0
Ralstonia picketti (n=29)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	8	0	0	0	0

İn some clinical samples more than one agent was isolated. HAI: Healthcare-associated infection; CoNS: Coagulase-Negative Staphylococcus

Table 3. Hand hygiene practices of the health care providers (2012–2021)

	Years									
	2012 %	2013 %	2014 %	2015 %	2016 %	2017 %	2018 %	2019 %	2020 %	2021 %
Hand hygiene	77	78	81	86	86	83	91	81	91	94

than adults regarding HCAIs due to vascular access problems, frequent drug administration requirements, and the need for more frequent nurse care in PICUs.[8] Studies have shown that the HCAI rates in PICU range from 3.6% to 20% worldwide.[9] These rates in Türkiye differ from 2.9% to 43.9% in the pediatric ICUs[7] and from 3.2% to 42.3% in the neonatal ICUs.[10] In our study, the HCAI rate was 3.47% in the first five years and 2.26% in the second five years. Although our rates are low compared to world data, it was noticeable that there was a 1.21% decrease in the second five years.

A study conducted in the PICU in the USA reported that the most common HCAI was BSI (41.3%), followed by VAP (22.7%).[11] Maoulainine et al.[12] reported that 79.6% of HCAIs were ESBL-producing GNB, and the most common pathogen was *K. pneumoniae* (39.7%). Another study reported that the most common microorganisms isolated were GNB (79.8%), in which *Klebsiella pneumonia* was the most common pathogen (n=22, 29.3%). Consistent with the literature, we found GNB as the most common cause of HCAI in our PCVS-ICU, i.e., 73.6% of 76 isolates in the first five years, in which *K. pneumoniae* was the most common (26%). The second most common organism was *Candida spp*. (26.3%). In the second five years, of the 94 isolates, 69% were GNB, which included *Candida spp*. (31%).[13,14]

In a prospective study conducted in Spain, bacteremia was the most common HCAI in the PICU, followed by respiratory tract infections and UTIs. In their study, the most common pathogens were Coagulase-negative *Staphylococci, Pseudomonas aeruginosa,* and *E. coli*.[15] On the other hand, the most common HCAI pathogens in our PCVS-ICU were P. aeruginosa in pneumonia (might or might not be associated with ventilation support), *Stenotrophomonas (Xanthomonas) maltophilia* in bacteremia, and *E. coli* in UTI.

During the first five years of the study, colistin resistance was not observed, but carbapenem resistance was high. In contrast, colistin resistance was 100%, and pan-resistant carbapenem strains were observed in the second five years. As our hospital is a tertiary referral center for pediatric CVS, most admitted patients undergo surgery to correct complex cardiac pathologies with an increased tendency to prolonged hospital stays, mechanical ventilation, and HCAIs. Moreover, most of these operated children had syndromes or accompanying respiratory, neurologic, or gastrointestinal health problems. The use of broad-spectrum antibiotics as empirical treatment in these patients might lead to increased antibiotic resistance.

In many studies conducted with *S. maltophilia*, most isolates were from ICU patients.[16] Nosocomial infections caused by *S. maltophilia* are mostly defined as lung infections, urinary system infections, catheter-related infections, bacteremia, and sepsis.[17,18]

In hospitals, these bacteria can be isolated from central venous or arterial monitors, dialysis machines, disinfectant and hand washing solutions, deionized water, nebulizers, ventilation systems, tap water, shower heads, and the hands of healthcare personnel.[19]

In this study, 5% of the pathogens isolated in the first five years were *S. maltophilia*. However, it increased to 50% in the second five years, probably from the medical materials used. Moreover, the increase in hospital care-associated pneumonia cases in the second five years might be due to COVID-19.

During the COVID-19 pandemic, hand hygiene rates have increased, and additional measures such as restriction of intensive care visits, more protective measures such as masks and visors, and more frequent cleaning of the unit have been implemented by the health care providers.

In many epidemic investigations, the causes of the epidemic were related to the insufficient personnel or the acceptance of patients above capacity and the low level of hand hygiene compliance.[20,21] The prevalence of HCAIS decreased with increased compliance with hand hygiene in health professionals.[22,23] Although compliance with hand hygiene is the easiest, cheapest, and most effective method in preventing HCAIs, studies have shown that hand hygiene compliance rates remain about 30%–60%, and some do not exceed 50%.[24]

In our study, hand hygiene rates increased markedly (77%–86% from 2012 to 2017 and 83%–94% from 2018 to 2021) owing to training and awareness during the COVID-19 pandemic.

The Institute for Healthcare Improvement has developed the concept of a "care package" to provide the best possible multidisciplinary care for patients. Care packages should always apply to patients of all conditions and be evidence-based.[25] With the care package, it is important to reassure healthcare workers that they are part of the team and that zero infection is possible. In the hospital, care packages (ventilator-associated pneumonia care package, urinary catheter-related urinary system infection care package, and central venous catheter-related bloodstream infection care package) created by the infection control team according to the institution profile are used.

Covering the dressing of the central catheter with a semi-permeable and transparent dressing ensures that the catheter entry site can be observed, preventing frequent dressing changes. The care packages we apply in our hospital include basic components about field cleaning, catheter application procedure, and care, and their application is ensured. As a result, infection rates have decreased with the implementation of care packages in our hospital.

The care packages applied in infection control are an application that includes all these steps: education of healthcare workers, provision of care, evaluation, and recording of data for success in the fight against infection. Infection control section management, personnel training, procedural control, compliance, and calculation of surveillance are of great importance in the reliable implementation of care packages.[26]

After the training given before the application and the feedback in the field, the infections decreased shortly after the implementation of the care packages in our study. We attributed this to increased attention to the issue of infection control and strict adherence to infection control measures.

Serious measures are required to ensure infection control in the ICU. However, despite all efforts and precautions, the infection can still be observed. Factors such as inadequate personnel per patient, a high number of chronic patients who need to be hospitalized for a long time, and the inadequacy of physical facilities increase the number of HCAIs. We think that the increased compliance with all infection control measures, from hand hygiene to unit hygiene, is effective in the decrease in infection rates in this period. Infection control measures should be applied meticulously, and personnel training and infection frequency should be reviewed regularly. Awareness of HCAIs should be increased by conducting regional and multicenter current studies on pediatric surgery intensive care units.

Disclosures

Ethics Committee Approval: The study was approved by The Kartal Koşuyolu High Specialization Training and Research Hospital Clinical Research Ethics Committee (Date: 22/03/2022, No: 2022/6/578).

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

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