OPEN ACCESS

GAVIN PUBLISHERS

Research Article

Pediatric Bloodstream Infections in Saudi Arabia: A Microbiological Analysis

Abdulrahman Alodayani[1], Naoufel Kaabia[1*], Faten Basnawi[2], Nada Alharbi[1], Abdullah Alfarhoud[2], Rana Almaghrabi[2], Nabiha Bouafia[1]

[1]Infection Prevention and Control Center of Excellence, Prince Sultan Military Medical City, P.O Box 7897 Riyadh 11159 Saudi Arabia

[2]Pediatric Infectious Diseases Unit, Prince Sultan Military Medical City, P.O Box 7897 Riyadh 11159 Saudi Arabia

*Corresponding author: Naoufel Kaabia, Infection Prevention and Control Center of Excellence, Prince Sultan Military Medical City, P.O Box 7897 Riyadh 11159 Saudi Arabia

Abstract

Background: Blood cultures are essential for diagnosing Bloodstream Infections (BSIs) in children. Understanding the specific pathogens involved is crucial for accurate diagnosis and appropriate antimicrobial therapy. Objectives: to describe the demographic and microbiological characteristics of pediatric patients with Positive Blood Cultures (PBCs) and determine the resistance profile of isolated bacteria. **Methods:** This retrospective study analyzed blood culture results from pediatric patients at a tertiary hospital in Riyadh, Saudi Arabia, from February to July 2019. Demographic and microbiological data were extracted. **Results:** Of 132 PBCs from 108 patients (62 male, 46 female), 35 (26.5%) were contaminated, leaving 97 True Positive Blood Cultures (TPBCs). Gram-Negative Bacilli (GNB) were predominant in TPBCs (57.5%), followed by gram-positive cocci (47.5%). Coagulase-Negative Staphylococci (CONS), *Klebsiella pneumoniae*, and *Serratia marcescens* were the most frequent isolates. All Enterobacterales isolates were Carbapenems-sensitive, but 43.5% were extended-spectrum β-lactamase (ESBL) producers. **Conclusion:** This study highlights the high rate of blood culture contamination in pediatric patients. GNB, particularly ESBL-producing Enterobacteriaceae, were the predominant pathogens causing BSIs, emphasizing the need for appropriate antimicrobial stewardship.

Introduction

Blood cultures are considered an important widely used investigational tools in pediatrics. They help isolate the causative organism, identify its susceptibilities, and help in directing further treatment and overall management. In adult patients, blood culture is a relatively standardized process with clear guidelines supported by extensive data, however, in pediatrics, blood culture practices vary according to the institution due to the lack of published data and guidelines [1]. Bloodstream infections (BSIs) can be community or healthcare acquired. In addition, the source of bacteraemia can be categorised as either primary, where there is no clear source of infection, or secondary, due to focal infection in one or more organs in the body [2]. Also, blood cultures may sometimes be a false positive due to contamination, defined by the presence of bacteria, from the environment, and not from the patient's bloodstream. This emphasizes the necessity to differentiate a true BSI from a contamination, which is a challenge for all physicians [3]. BSI is a frequent cause of morbidity, and leads to high mortality rate in pediatric population, in addition, bacterial resistance is acknowledged as a major medical threat in most healthcare systems. Therefore, there is a crucial need for antibiotic guidance based on the prevalence of bacterial aetiology and antibiotic resistance trends collected from local antibiograms data [2].

The incidence of multidrug-resistant organism (MDRO) infections in the pediatric population is increasing, especially due to gram-

negative Bacilli (GNB), with higher mortality rates [4,5]. In daily clinical practice, physicians commence empirical antimicrobial therapy before getting blood culture results; the choice of empirical treatment depends on several factors related to the patient, local ecology, and BSI epidemiology. Consequently, monitoring and surveying Positive Blood Cultures (PBCs) are important in every hospital to guide an appropriate empirical antibiotics prescription. Therefore, this study aimed to describe the demographic and microbiological data of pediatric patients with Positive Blood Cultures (PBCs) and determine the resistance profile of isolated bacteria.

Material and Methods

This study was an observational laboratory survey of identified blood cultures conducted at Prince Sultan Military Medical City (PSMMC) in Riyadh, Saudi Arabia, during the period of February to July 2019. All PBCs were collected from the microbiology laboratory during the study period. In addition, demographic data were collected and illustrated as gender, age, date of admission, origin of the infection, patient location, and sample collection date. All blood cultures were managed in the microbiology laboratory at PSMMC, which is certified by the College of American Pathologists. Microbial identification and susceptibility testing were performed in accordance with the Clinical & Laboratory Standards Institute guidelines. The frequency of resistance was calculated as the percentage of any given microorganism with intermediate or full resistance divided by the total number of isolates tested for a particular antibiotic. All PBCs from pediatric patients (aged ≤14 years) were included, and duplicate blood cultures were excluded. The following definitions were used in this study:

PBCs: At least one micro-organism growth from blood culture taken in a patient with no prior PBC for the same organism and location in ≤14 days across calendar months and different facility admissions.

Duplicate PBCs (DPBCs): These were PBCs from the same patient and with the same microorganism within 14 calendar days from the first PBC.

Contaminated blood cultures (CBCs): A set of blood cultures grow thing at least one of the following bacteria in ≤50% of the blood culture samples taken from one patient on the same day (*Corynebacterium spp*, alpha-hemolytic Streptococci, coagulase-negative Staphylococci, *Propionibacterium spp*, *Micrococcus spp*, and *Bacillus spp*.) [6]

Polymicrobial infections (PMIs): Growth of more than one organism from a single blood culture sample and/or growth of more than one microorganism from separate blood culture specimens during the same period (within 14 days).

Relapsed infections (RIs): Occur when the same bacteria are isolated from PBCs for the same patient within two weeks after the first PBC.

Recurrent infections (REIs): Occur when different bacteria are isolated from PBCs for the same patient at least 14 days after the last PBC.

PBCs incidence density rate (IDR): "The number of true PBCs (TPBCs) per patient per month identified >3 days after admission to the location (if monitored by inpatient location), facility (if monitored by overall facility-wide inpatient=FacWideIN), divided by the number of patient days (PDs) for the location or facility, and multiplied by 1000".

Hospital-onset (HO): PBCs obtained >48 hours after admission.

Community-onset (CO): PBCs obtained from outpatients or inpatients ≤48 hours after admission.

All data were interpreted and analyzed using descriptive statistics and assessed based on data normality. Furthermore, continuous variables such as, admission date, specimen collection date, and age, were calculated as duration (days). others variables such as gender, patient location, source of infection, samples type, site of the sample, organism species, and antimicrobial resistance pattern were presented as frequencies (N) and percentages (%).

Results

This study was carried out at PSMMC, in Riyadh, Saudi Arabia, during the period of February to July 2019, 132 PBCs were collected from 108 patients. Patients had age ranged from 1 day to 12 years (mean: 1.9 years). Among the 108 patients, 62 (57.4%) and 46 (42.6%) were male and female, respectively. Of the 132 PBCs, 35 (26.5%) were contaminated, and 97 (73.5%) were TPBCs.

CBC samples were documented mainly from outpatient departments (43%), followed by emergency rooms (17%), and infants were observed to have the highest rates of CBC samples (60%). The most frequently isolated bacteria from the CBC samples were coagulase-negative Staphylococci (16 cases), *Streptococcus viridans* (10 cases), *Bacillus spp*. (four cases), and *Corynebacterium spp*. (four cases).

Among the 97 TPBCs, 93 (96%) showed bacterial growth, nine with more than one bacterium. GNB were noted in 56 cases (57.5%), followed by gram-positive cocci (GPC) in 46 cases (47.5%). In addition, four (4%) TPBCs showed fungal infection (*Candida albicans* in three cases and *C. tropicalis* in one case). Bacteraemia was documented in 62 (64%) blood samples from patients aged <1 year, of whom 47 (48.5%) were >1-month-old. In addition, 52 TPBCs were HO, while 45 were CO. Intensive Care

Units (ICUs) and pediatric long stays were the main locations for patients with HO TPBCs in 40% and 30.5% of cases, respectively (Table 1).

Epidemiological data	True positive blood cultures (n=97 cases) (80 patients)		
	Hospital onset (52 cases)	**Community onset** (45 cases)	**Total** (97 cases)
Gender (80 patients)			
Male	18 (22.5%)	19(23.7%)	37 (46%)
Female	22(27.5%)	21(26.2%)	43 (54%)
Age			
Neonatal: 1–30 days	9 (11.2%)	6 (7.5%)	15 (15.5%)
Infant: 1 m to 1 y	24 (30%)	23(28.7%)	47 (48.5%)
Toddler: 1–3 y	11(13.7%)	3(3.7%)	14 (14.5%)
Children: 3–14 y	8 (10%)	13(16.2)	21 (21.5%)
Locations TPBCs (n=97 cases)			
ICU	21(21.6%)	6 (6.2%)	27 (28%)
Oncology-OST-HSCT	8 (8.2)	3(3%)	11 (11.5)
Medical/Surgical wards	7(7.2%)	17(19.5%)	24 (24.5%)
Long stay	16 (16.5)	0 (0%)	16 (16.5)
OPD	0 (0%)	19(19.5)	19 (19.5%)
Microorganisms			
Gram-positive cocci	24(24.7%)	22 (22.6%)	46 (47.5%)*
Gram-negative *Bacilli*	34 (35%)	22(22.6%)	56 (57.5%)*
Fungi	3(3%)	1(1%)	4 (4%)
Site of Blood culture			
Peripheral	42 (43.3%)	43(44.3%)	85 (87.6%)
Central line	10 (10.3%)	2 (2.1%)	12 (12.4%)
Recurrent/Relapsed TPBC	12 (12.3)	5 (5.1%)	17 (17.5%)
Polymicrobial TPBC	8 (8.2%)	1(1%)	9 (9.5%)
14-day Mortality rate	7(8.7%)	2 (2.5%)	9(11.2%)
TPBC incidence density rate	3 cases/1000 patient days, Hospital-wide (9 cases/1000 PDs in ICUs)		
m: months; y: years; OST: Organ Solid Transplant; OPD: Outpatient Department; HSCT: Hematopoietic Stem Cell Transplant, *Nine blood cultures with two bacteria.			

Table 1: Epidemiological data of true positive blood cultures (TPBC) noted in pediatric patients.

Analysis of the TPBCs showed that Enterobacterales species were the predominant isolates in 41 cases, followed by coagulase-negative *Staphylococci* (19 cases), *Enterococcus faecalis* (11 cases), and *Staphylococcus aureus* (9 cases). Table 2 summarizes the list of all bacteria isolated from TPBCs according to the infection origin. GNB, mainly *Enterobacterales species*, were the major cause (58.5%) of HO TPBCs, followed by GPC (46.5%). However, GNB and GPC were equally responsible for CO TPBCs.

Isolated bacteria	Hospital onset 58 isolates	Community onset 44 isolates	Total 102 isolates
CONS	11	8	19 (18.5%)
Klebsiella pneumonia	10	4	(13.5%)
Serratia Marcescens	7	3	10 (10%)
Staphylococcus aureus	7	2	9 (9%)
Enterococcus faecalis	6	5	11 (10.5%)
Pseudomonas aeruginosa	8	2	10 (10%)
Acinetobacter baumannii	2	0	2 (2%)
E. coli	2	4	6 (6%)
Enterobacter cloacae	2	2	4 (4%)
Brucella spp	0	3	3 (3%)
Group B Streptococcus	0	3	3 (3%)
Stenotrophomonas maltophilia	2	1	3 (3%)
Others	1*	7**	8 (8%)

CONS: coagulase-negative Staphylococcus, *Citrobacter freundii* (1 case), **Peptococcus spp.* (2 cases)*, Haemophilus influenza* (1 case), *Prevotella melaninogenica* (1 case), *Salmonella spp.* (1 case)*, Streptococcus pneumoniae* (1 case), *Group D Streptococcus* (1 case)

Table 2: List of bacteria isolated from TPBC in pediatric patients.

Regarding antibiotic resistance patterns, our study showed that out of 30 Enterobacteriaceae isolates, resistance to third-generation cephalosporins and piperacillin/tazobactam were noted in 13 cases (43.5%) and 8 cases (26.5%), respectively. However, all Enterobacteriaceae species were sensitive to carbapenems. For GPCs, vancomycin-resistant Enterococcus (VRE), and methicillin-resistant *Staphylococcus aureus* (MRSA) were noted in one and two TPBC, respectively. The resistance rates of the most frequently isolated bacteria to the commonly used antibiotics are listed in Table 3.

Antibiotics	*S. aureus* (9 isolates)	*Enterococcus faecalis* (11 isolates)	*K. pneum* (14 isolates)	*S. marc* (10 isolates)	*E. coli* (6 isolates)	*P. aeru* (9 isolates)
Methicillin	2/9	NA	NA	NA	NA	NA
Clindamycin	0/9	NA	NA	NA	NA	NA
Rifampicin	0/9	4/11	NA	NA	NA	NA
SXT	0/9	0/11	4/14	0/10	3/6	NA
Gentamycin/ Amikacin	0/9	1/11	2/14	3/10	1/6	0/9
Vancomycin	0/9	1/11	NA	NA	NA	NA

Ciprofloxacin	0/9	4/11	3/14	1/10	2/6	0/9
C3G (Ceftaz for PA)	NA	NA	7/14	2/10	4/6	0/9
Amox-Ac clavulanic	NA	1/11	4/14	2/10	1/6	NA
Meropenem/ Imipenem	NA	NA	0/14	0/10	0/6	2/9
Piperacillin/ Tazobactam	NA	NA	4/14	2/10	2/6	2/9
pneu: *pneumonia*; marc: *marcescens*; aeru: *aeruginosa*; PA: *Pseudomonas aeruginosa*; SXT: co-trimoxazole; NA: not applicable, C3G: third-generation cephalosporin						

Table 3: Resistance profile of the most frequently isolated bacteria.

Discussion

Although it is not the most sensitive technique, blood culture is considered the gold standard and clinically relevant microbiological diagnostic tool for BSIs, directing appropriate antibiotics prescription. However, CBCs, which cause false-positive results, remain challenging for physicians and clinical microbiologists [7]. The number of cultures sets that grow specific organisms can help differentiate contamination from true infection; if only one of a given set grows an organism, this generally represents a contaminant, and multiple sets will usually grow the same organism in true-positive bacteraemia. However, many studies have suggested that these criteria are insufficient and should not be used alone to differentiate true-positive results from contaminants [8,9]. Therefore, CBCs cause the initiation of unnecessary broad-spectrum antibiotic prescription. This carries a risk of modifying and changing the intestinal microbiome, and in infancy, this has been shown to increase the risk of asthma, allergies, obesity, celiac disease, and antibiotic resistance later on [10,11].

The present study showed a high percentage of CBCs (26.5%). This rate could be higher if the TPBCs due to coagulase-negative Staphylococci are included, as this group of microorganisms is generally more responsible for contamination than real infections. However, because this study is not a clinical survey, it is difficult to distinguish between CBCs and real BSIs due to coagulase-negative Staphylococci.

This high rate of CBCs in pediatric patients can be explained by difficulties in collecting blood samples from this patient group and poor aseptic techniques. In neonates and small infants, phlebotomy is difficult sometimes and potentially harmful in certain situations [12,13]. In addition, chlorhexidine gluconate products are not approved for use in infants <2 months old, and iodine-containing antiseptic is contra indicated for use in neonates due to the potential of developing subclinical hypothyroidism. Therefore, 70% isopropyl alcohol remains the most used antiseptic, which requires a longer contact time to dry, and nurses sometimes ignore this [14]. In a recent study, Maeda et al. found that chlorhexidine gluconate-ethanol skin preparations were more effective than povidone-iodine disinfection before venepuncture in children to prevent blood culture contamination [15]. Considering these, strict adherence to sterile venepuncture techniques by well-trained pediatric phlebotomy teams should be enforced.

In the present study, the incidence of HO TPBCs was slightly higher than that of CO TPBCs, with an incidence rate of three episodes per 1000 PDs in all pediatric wards and nine episodes per 1000 PDs in the pediatric and neonatal ICUs. This predominance of HO TPBC could be explained by our hospital's type of inpatients and activities. First, most patients were transferred from other healthcare facilities because our facility is a referral center for hematopoietic stem cell and solid organ transplants. Therefore, many patients at our facility were immunocompromised. Second, many invasive and complicated procedures and surgeries are performed in our institution. These factors contributed to the incidence of nosocomial BSIs.

With regard to age, almost half of the PBCs in this study were observed in children aged between 1 month and 1 year. In a national BSI survey conducted in the United Kingdom from January 2009 to March 2010, 8718 episodes of BSI were reported; 1734 were nosocomial BSIs, giving a rate of 4.74 episodes per 1000 admissions. In addition, the median age at infection was 1 year old, and 54% of the infections were in males [16]. In another prospective study in the Pediatrics ICU of a tertially and regional referral hospital in North India, conducted during one-year (July 2003-July 2004), 116 episodes of primary BSIs were noted in 86 (30%) patients, with an incidence rate of 31.2 episodes per 1000

PDs. Furthermore, 73.3% of patients had single episode of BSIs, and 26.7% presented multiples episodes [17]. A survey conducted in 2015, including 300 children, at the Institute of Child Health and Hospital for Children, Chennai, observed that maximum culture positivity was noted in children aged 1-3 months old (2).

In the present study, the second main finding was the high prevalence of GNB, especially in HO TPBCs. During the last two decades in Saudi Arabia and many countries, there has been a change in the epidemiological and ecological profile of TPBCs among pediatric patients. Recent studies, including the present study, confirm the predominance of GNB at the expense of GPC with an increased rate of extended-spectrum β-lactamase-producing bacteria (ESBL) [18-21]. Similar findings were reported in China, where a retrospective study conducted at thirteen teaching hospitals from 2016 to 2018 noted that among 9345 nonduplicate bloodstream isolates, the top ten collected bacteria included: CONS (44.4%), *E. coli* (10.2%), *K. pneumoniae* (5.9%), *S. aureus* (5.0%), *Streptococcus pneumoniae* (4.9%), *P. aeruginosa* (2.8%), *Enterococcus faecium* (2.7%), *Stenotrophomonas maltophilia* (2.4%), *Salmonella spp* (2.3%), and *Streptococcus agalactiae* (2.0%) [22]. Additionally, a cross-sectional study performed to identify the predominant group of causative microorganisms at a tertiary healthcare in Peshawar, in 2018 reported that gram-negative and gram-positive bacteria were identified in 71.1% and 28.9% of isolates, respectively [23]. However, a retrospective survey of TPBCs from 2007 to 2016 in Spain, including level I and II hospitals, showed that the most frequently isolated bacteria was *Streptococcus pneumoniae* (29.2%), with a decrease in the number of cases between 2008 and 2015. Staphylococcus aureus was the second common bacteria (19.2%), and 21.7% of them were methicillin-resistant. Furthermore, Escherichia coli was the most frequent organisms in children aged <3 months old [4]. Similarly, a multicentre, prospective cohort at 10 pediatric hospitals in Switzerland reported that E coli (20%) was the main organism identified, followed by S aureus (15%), CONS (11%), and S pneumoniae (10%) [24].

Pneumococcal bacteraemia was very rare in our survey (only one case), although *Streptococcus pneumoniae* is the leading isolate of CO TPBCs [25]. In addition, after introducing the pneumococcal vaccine, many studies noted a net decrease in pneumococcal bacteraemia in children [26,27].

The antibiotic stewardship team at our facility needs to consider these findings. The epidemiology of BSIs is dynamic because they depend on microbiological, host, and healthcare system factors. For example, the types and frequencies of microorganisms responsible for PBCs vary between developing and developed countries, hospital levels (primary and tertiary), and in the same institution between medical, surgical wards, and ICUs. In addition, the infection origin (CO or HO) and underlying diseases play important roles in determining the type of causative bacteria.

Regarding antibiotic sensitivity and resistance patterns, this study showed that 43.5% of Enterobacteriaceae were resistant to third-generation cephalosporins; however, a low resistance rate of MRSA and VRE and the absence of carbapenem-resistant Enterobacteriaceae were observed. Third-generation cephalosporins are frequently chosen as initial empirical antibiotics in many hospitals for community-acquired bacteraemia. However, recent studies have shown an increasing rate of resistant organisms in CO infections due to the overuse of ceftriaxone, cefotaxime, or ceftazidime, by the production of ESBL or AmpC beta-lactamases [2,22,28].

In addition, in a study conducted in USA during the period 2005 to 2011, on pediatric antimicrobial susceptibility trends, carbapenems were the most effective antibiotics against gram-negative organisms. Furthermore, the incidence of MRSA was 50%, and Enterococcus faecium showed 25% and 45% susceptibility to ampicillin and vancomycin, respectively [2].

Our study had some limitations. First, it was performed in a single tertiary pediatric hospital, and the incidence of serious infections is higher in tertiary centres. Therefore, this study's results cannot be generalized to other hospitals. Second, our data were obtained and analysed retrospectively from medical patient records. Lastly, cost estimation due to false positive or contaminant results that might lead to unnecessary admissions and investigations could not be attained.

Conclusion

The main results of this study were (i) the predominance of GNB in BSIs among the pediatric population, especially when it occurs after hospital admission, (ii) the high rate of Enterobacteriaceae resistance to third-generation cephalosporins, and (iii) the low incidence of MRSA and VRE. Therefore, we recommend that our hospital's antibiotic stewardship team considers these findings when preparing hospital guidelines for empirical antibiotics for BSIs. Finally, a high rate of CBCs was observed among the pediatric population. Hence, a quality improvement project should be implemented to investigate and take action to reduce this rate.

Acknowledgment

Funding

been used only to pay Editage service and publication fees of this manuscript

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Sharing Statement

Raw data were generated at Infection and Control Center of Excellence, Prince Sultan Military Medical City. Derived data supporting the findings of this study are available from the corresponding author Dr Naoufel Kaabia on request through his E-mail.

Authors' Contributions

Naoufel Kaabia and Abdulrahman Alodayani are the principal investigators, they prepared the proposal, did data interpretation, and wrote the draft manuscript. Faten Basnawi did data analysis and interpretation, literature review, and wrote the draft manuscript. Nada Alharbi did data collection and data entry, prepared tables and figures. Abdullah Alfarhoud did literature review and wrote the manuscript. Rana Almaghrabi did data analysis and revised the manuscript. Nabiha Bouafia revised the manuscript. All authors have approved the final article.

Informed Consent

Not applicable in the current study, because it involved only anonymous data extracted from infection control database.

References

1. Bard JD, TeKippe EM (2016) Diagnosis of bloodstream infections in children. J Clin Microbiol 54: 1418-1424.

2. Wattal C, Goel N (2020) Pediatric blood cultures and antibiotic resistance: an overview. Indian J Pediatr 87: 125-131.

3. Dargère S, Cormier H, Verdon R (2018) Contaminants in blood cultures: importance, implications, interpretation and prevention. Clin Microbiol Infect 24: 964-969.

4. Ferreira M, Santos M, Rodrigues J, Diogo C, Resende C, et al. (2021) Epidemiology of bacteremia in a pediatric population - A 10-year study. Enferm Infecc Microbiol Clin (Engl Ed) S0213–005X.

5. Ames SG, Davis BS, Angus DC, Carcillo JA, Kahn JM (2018) Hospital variation in risk-adjusted pediatric sepsis mortality. Pediatr Crit Care Med 19: 390-396.

6. Roth A, Wiklund AE, Pålsson AS, Melander EZ, Wullt M, et al. (2010) Reducing blood culture contamination by a simple informational intervention. J Clin Microbiol 48: 4552-4558.

7. Hemeg HA, Almutairi AZ, Alharbi NL, Alenezi RF, Alturkostani MA, et al. (2020) Blood culture contamination in a tertiary care hospital of Saudi Arabia. A one-year study. Saudi Med J 41: 508-515.

8. Hall KK, Lyman JA (2006) Updated review of blood culture contamination. Clin Microbiol Rev 19: 788-802.

9. Weinstein MP, Reller LB, Murphy JR, Lichtenstein KA (1983) The clinical significance of positive blood cultures: a comprehensive analysis of 500 episodes of bacteremia and fungemia in adults. I. Laboratory and epidemiologic observations. Rev Infect Dis 5: 35-53.

10. Gibson MK, Crofts TS, Dantas G (2015) Antibiotics and the developing infant gut microbiota and resistome. Curr Opin Microbiol 27: 51-56.

11. Sander SD, Andersen AMN, Murray JA, Karlstad Ø, Husby S, et al. (2019) Association between antibiotics in the first year of life and celiac disease. Gastroenterology 156: 2217-2229.

12. Alnami AY, Aljasser AA, Almousa RM, Torchyan AA, BinSaeed AA, et al. (2015) Rate of blood culture contamination in a teaching hospital: a single center study in Saudi Arabia. J Taibah Univ Medical Sci 10: 432-436.

13. Sallam L, Kaabia N, Al-Aidaroos A, Al-Darsony S, Al-Odayani A (2021) Predominant bacterial pathogens and resistance profile of blood isolates: blood cultures surveillance from tertiary teaching hospital. Acta Sci Microbiol 4: 46-53.

14. Murphy C, Andrus M, Barnes S, Garcia R, Juraja M, et al. (2009) Guide to the elimination of catheter-related bloodstream infections. Washington, DC.

15. Maeda N, Mori N, Shinjoh M, Komiyama O, Takahashi T (2021) Comparison of 0.5% chlorhexidine gluconate alcohol with 10% povidone-iodine for skin disinfection in children to prevent blood culture contamination. J Infect Chemother 27: 1027-1032.

16. Blackburn RM, Henderson KL, Minaji M, Muller-Pebody B, Johnson AP, et al. (2012) Exploring the epidemiology of hospital-acquired bloodstream infections in children in England (January 2009-March 2010) by linkage of national hospital admissions and microbiological databases. J Pediatric Infect Dis Soc 1: 284-292.

17. Lakshmi KS, Jayashree M, Singhi S, Ray P (2007) Study of nosocomial primary bloodstream infections in a pediatric intensive care unit. J Trop Pediatr 53: 87-92.

18. Al-Zamil FA (2008) Bacteremia in children at the University Hospital in Riyadh, Saudi Arabia. World J Pediatr 4: 118-122.

19. Al-Abdely HM, Alshehri AD, Rosenthal VD, Banjar W, Mohammed YK, et al. (2017) Device-associated infection rates in Intensive Care Units of five cities of the Kingdom of Saudi Arabia: International nosocomial infection control consortium (INCC) findings. Can J Infect Control 32: 31-36.

20. Bandy A, Almaeen AH (2020) Pathogenic spectrum of blood stream infections and resistance pattern in gram-negative bacteria from Aljouf region of Saudi Arabia. PLoS One 15: e0233704.

21. Babay HA, Twum-Danso K, Kambal AM, Al-Otaibi FE (2005) Bloodstream infections in pediatric patients. Saudi Med J 26: 1555-1561.

22. Qiu Y, Yang J, Chen Y, Yang J, Zhu Q, Zhu C, et al. (2021) Microbiological profiles and antimicrobial resistance patterns of pediatric bloodstream pathogens in China, 2016-2018. Eur J Clin Microbiol Infect Dis 40: 739-749.

23. Muhammad A, Noor Khan S, Jamal T, Ul Haq I, Jabbar A, et al. (2020) Bacterial spectrum and antimicrobial profile of pediatric blood stream

infection at a tertiary care hospital in Pakistan. Chin Med Sci J 35: 315-322.

24. Agyeman PKA, Schlapbach LJ, Giannoni E, Stocker M, Posfay-Barbe KM, et al. (2017) Epidemiology of blood culture-proven bacterial sepsis in children in Switzerland: a population-based cohort study. Lancet Child Adolesc Health 1: 124-133.

25. Gomez B, Hernandez-Bou S, Garcia-Garcia JJ, Mintegi S (2015) Bacteremia in previously healthy children in emergency departments: clinical and microbiological characteristics and outcome. Eur J Clin Microbiol Infect Dis 34: 453-460.

26. Greenhow TL, Hung YY, Herz A (2017) Bacteremia in children 3 to 36 months old after introduction of conjugated Pneumococcal vaccines. Pediatrics 139: e20162098.

27. Zaitoon H, Bamberger E, Yaniv L, Mendelson B, Srugo I, et al. (2020) A retrospective study of the impact of Pneumococcal conjugate vaccine-13 immunization in a Northern Israel hospital. Isr Med Assoc J 22: 71-74.

28. Mao S, Ge Z, Zhao H, Cao J, Xia Z (2019) Analysis on distribution and drug resistance of pathogen caused community-onset bloodstream infection. Zhonghua Wei Zhong Bing Ji Jiu Yi Xue 31: 67-72.