Darji & Patel| Article 8469
J Pure Appl Microbiol. 2023;17(2):911-918. doi: 10.22207/JPAM.17.2.18
Received: 31 January 2023 | Accepted: 08 March 2023
Published Online: 21 April 2023

P-ISSN: 0973-7510; E-ISSN: 2581-690X

RESEARCH ARTICLE OPEN ACCESS

Central Line Associated Blood Stream Infection: Microbiological Profile and its Antimicrobial Susceptibility Pattern at Tertiary Care Centre

Sachin M. Darji* and Neha Patel

Department of Microbiology, GCS Medical College, Hospital and Research Centre, Ahmedabad, Gujarat, India.

Abstract

Central venous catheters are commonly inserted to monitor patients with critical illnesses. Even when used to treat very ill patients, they are susceptible to widespread headaches, including central line-associated bloodstream infections (CLABSI). Central line-associated bloodstream infection (CLABSI) is one of the most significant HAIs, associated with excess mortality of 12–25%. To discover CLABSI cases, microbiological profiles, and their antimicrobial susceptibility. The study was conducted in an intensive care unit over a period of 12 months. 150 blood samples and catheter tips were collected for the culture of suspected or secondary bacteremia. CLABSI is described as being consistent with the CDC's proposal. Automated VITEK 2 technology identifies bacterial isolates and investigates their antimicrobial susceptibility. Out of 150 samples, 50 showed no growth, 45 showed colonizers, 40 showed CLABSI, and 15 showed secondary infection. Fifty-five had positive blood cultures, 15 of whom had another source of infection. In our study, the CLABSI rate was 7.8/1000 central venous days. Rigorous implementation of the system and maintenance of the central line bundle are mandatory to prevent colonization.

Keywords: Central Venous Catheter, Intensive Care Units, Sepsis

***Correspondence:** sachin.chetna@gmail.com

Citation: Darji SM, Patel N. Central Line Associated Blood Stream Infection: Microbiological Profile and its Antimicrobial Susceptibility Pattern at Tertiary Care Centre. *J Pure Appl Microbiol.* 2023;17(2):911-918. doi: 10.22207/JPAM.17.2.18

INTRODUCTION

Central venous catheters (CVCs) are inserted in seriously ill patients. Its inevitable use makes patients more vulnerable to headaches, which consist of central line-related bloodstream infections (CLABSIs). The problem of CLABSIs has received increasing interest in recent years.[1] The prevention of CLABSI consists of the development of information, guidelines, package care, the most sterile barrier, the use of 2% chlorhexidine, early catheter elimination, and the use of antimicrobial catheters and antimicrobial catheter lock solution.[2] The main objective of the present study was to determine the microbiological profile and antimicrobial susceptibility pattern of isolated bacteria from CLABSIs in an intensive care unit. Central line-associated bloodstream infections (CLABSIs) are one of the most critical HAIs, with an excessive mortality rate of 12–25%.[3]

MATERIALS AND METHODS

In general, 150 blood samples and catheter tips were collected for culture when primary or secondary bacteremia was suspected in patients admitted to the tertiary care centre's intensive care unit over a one-year period. Central lines were inserted with strict aseptic precautions as consistent with the preferred protocol. Catheter tip specimens were processed using the conventional culture plate method; a 4 cm segment of the catheter tip was cut and kept in a sterile universal container. It was transported immediately, preventing drying and allowing it to be processed within two hours of being collected. Blood samples for a culture investigation have been collected using an ideal venepuncture technique and then processed as per standard technique by incubating the bottles in Bac T/Alert 3D.[4-6] In positive cultures, bacterial colonies have been processed and identified. The phenotypic identity of pathogens and antimicrobial sensitivity were performed by way of an automatic approach, VITEK 2,[7] as per Clinical and Laboratory Standard Institute (CLSI) guideline 2022.[8] The CLABSI rate was calculated by means of the following equation[9]:

CLABSI rate per 1000 central line days

$$\frac{\text{Number of CLABSI cases}}{\text{Number of central line days}} \text{ X } 1000$$

Statistical analysis

Statistical analysis was done using Microsoft Excel 2007 (Microsoft Corp., Redmond, WA, USA) and SPSS version 20 (IBM Corp., Somers, NY, USA). Frequencies and percentages were calculated. The Chi-square test was used to calculate the relationship between pathogens, isolated organisms, and infection. The significance level was set at $P< 0.05$.

RESULTS

The categorization of patients on the basis of CLABSI is shown in Table 1. A total of 150 tip cultures were acquired by means of the laboratory from intensive care unit patients with a clinical diagnosis of sepsis following central venous catheterization. Of the 150 patients, 45 (30%) had colonised catheter tips. Among the colonised catheters, Gram-positive cocci 17 (37.78%) had

Table 1. Categorization of patients on the basis of central line associated bloodstream infections

Blood culture	Tip culture	Impression	No. of cases (%)	Interpretation
Positive	Positive (similar isolate)	CLABSI	40 (26.7%)	CLABSI present
Negative	Positive	Catheter tip colonization	45 (30%)	CLABSI absent
Positive	Negative	Secondary infection	3 (2%)	CLABSI absent
Positive	Positive (different isolate)	Secondary infection	8 (5.33%)	CLABSI absent
Negative	Negative	Sterile	50 (33.33%)	CLABSI absent
Positive	Positive (similar isolate)	Secondary infection	4 (2.67%)	CLABSI absent

Table 2. Shows the antibiotic sensitivity pattern of Gram-positive isolates in cases of central line-associated bloodstream infection

Antibiotics	S/R (Sensitivity %)		
	Staphylococcus aureus (6)	*Staphylococcus haemolyticus* (4)	*Staphylococcus epidermidis* (3)
Cefoxitin	2/4 (33.3%)	2/2 (5%)	2/1 (66.7%)
Ciprofloxacin	2/4 (33.3%)	1/4 (25%)	1/2 (33.3%)
Clindamycin	3/3 (50%)	2/2 (5%)	2/1 (66.7%)
Cotrimoxazole	4/2 (66.7%)	3/1 (75%)	3/0 (100%)
Erythromycin	2/4 (33.3%)	2/2 (5%)	1/2 (33.3%)
Gentamicin	4/2 (66.7%)	3/1 (75%)	3/0 (100%)
Linezolid	6/0 (100%)	4/0 (100%)	3/0 (100%)
Vancomycin	6/0 (100%)	4/0 (100%)	3/0 (100%)
Tetracycline	1/6 (16.7%)	1/4 (25%)	1/2 (33.3%)
Penicillin G	0/6 (0%)	0/4 (0%)	0/3 (0%)

Table 3. Shows the antibiotic sensitivity pattern of Gram-negative isolates in cases of central line-associated bloodstream infection

Antibiotics	S/R (Sensitivity %)			
	Klebsiella pneumoniae(10)	*Escherichia coli* (8)	*Acinetobacter baumanii* (5)	*Pseudomonas aeruginosa* (4)
Amikacin	7/3 (70%)	6/2 (75%)	3/2 (60%)	2/2(50%)
Amoxycillin/Clavulinic acid	2/8 (20%)	3/5 (37.5%)	0/5 (0%)	-
Ampicillin	0/10 (0%)	0/8 (0%)	0/5 (0%)	-
Cefipime	3/7 (30%)	3/5 (37.5%)	1/4 (20%)	1/3(25%)
Ceftriaxone	1/9 (10%)	2/6 (25%)	0/5 (0%)	-
Ciprofloxacin	2/8 (20%)	2/6 (25%)	0/5 (0%)	3/1 (75%)
Imipenem	4/6 (40%)	5/3 (62.5%)	2/3 (40%)	2/2 (50%)
Meropenem	4/6 (40%)	4/4 (50%)	2/3 (40%)	2/2 (50%)
Ertapenem	4/6 (40%)	5/3 (62.5%)	2/3 (40%)	-
Piperacillin/Tazobactam	4/6 (40%)	4/4 (50%)	2/3 (40%)	2/2 (50%)
Cefoperazone/Sulbactam	4/6 (40%)	4/4 (50%)	4/1 (80%)	2/2 (50%)
Colistin	10/0 (100%)	8/0 (100%)	5/0 (100%)	4/0 (100%)
Tigecycline	8/2 (80%)	7/1 (87.5%)	5/0 (100%)	-
Cotrimoxazole	7/3 (70%)	6/2 (75%)	2/3 (40%)	1/3 (25%)

been the most common isolates observed, followed by *Klebsiella pneumoniae* 12 (26.67%), *Escherichia coli* 8 (17.78%), *Acinetobacter baumanii* 4 (8.89%), and *Pseudomonas aeruginosa* 4 (8.89%).

Of the 55 (36.7%) bloodstream infections, 40 (26.7%) had been diagnosed as CLABSI with a rate of 7.8/1000 central line days, and *Klebsiella pneumoniae* 10 (25%) was the most common isolate, followed by *Escherichia coli* 8 (20%) (Table 3), *Staphylococcus aureus* 6 (15%), *Acinetobacter baumanii* 5 (12.5%), *Pseudomonas aeruginosa* 4 (10%), *Staphylococcus haemolyticus* 4 (10%), and *Staphylococcus epidermidis* 3 (7.5%), and results of antibiotic susceptibility testing of the bacterial pathogens causing CLABSI are shown in Table 2 and Table 3.

Among 6 isolates of *Staphylococcus aureus*, 4 (66.67%) had been methicillin-resistant *Staphylococcus aureus* (MRSA), and among 7 coagulase-negative *Staphylococcus,* 5 (71.5%) had been methicillin-resistant coagulase-negative *Staphylococcus* (MR-CoNS). Among 27 gram-negative isolates, 16 (59.25%) had been carbapenemase-producing strains, and 20 (74.07%) were extended-spectrum beta-lactamase-producing strains [Table 4].

Table 4. Distribution of MRSA, MRCoNS, ESBL in patients with central line associated bloodstream infection

Isolates	No. (%)
MRSA	4 (66.67%)
MR-CoNS	5 (71.5%)
Carbapenemase	16 (59.25%)
Klebsiella pneumoniae (ESBL)	9 (90%)
Escherichia coli (ESBL)	2 (75%)
Acinetobacter baumanii (ESBL)	0 (100%)

MRSA is methicillin-resistant *Staphylococcus aureus*. MRCoNS is methicillin-resistant coagulase-negative *Staphylococcus* species. ESBL stands for extended spectrum beta-lactamases.

Table 5. Central line associated bloodstream infections in various clinical conditions

Underlying condition	No. (%)
Chronic obstructive pulmonary disease	25 (62.5%)
Renal failure	10 (25%)
Cerebrovascular accident	5 (12.5%)

The maximum number of underlying conditions for the CLABSI cases (n = 40) was chronic obstructive pulmonary disease (COPD) at 25 (62.5%), followed by renal failure at 10 (25%), and cerebrovascular accident at 5 (12.5%). [Table 5] Three (7.5%) out of the 40 CLABSI cases were fatal: one because of renal failure, one because of sepsis with multi-organ disorder syndrome (MODS), and two because of chronic obstructive pulmonary disorder [Table 6]. Mortality among jugular vein CLABSI was 0.67%. Mortality due to CLABSI with subclavian or femoral line catheterization was 0 and 1.33 percent, respectively [Table 7]. Out of 40 cases of CLABSI, the highest percentage of infection was observed in the femoral catheter (80%), followed by the jugular catheter (60%) and the subclavian catheter (30%). [Table 8].

Table 6. Mortality in patients with central line associated bloodstream infection cases

Outcome	No. (%)
Death	3 (7.5%)
Survival	37 (92.5%)

Table 7. Mortality in CLABSI in relation to central line catheters

Central line catheter type	No. (%)
Jugular	
CLABSI	1 (0.67%)
Non-CLABSI	4 (2.67%)
Femoral	
CLABSI	2 (1.33%)
Non-CLABSI	5(3.33%)
Subclavian	
CLABSI	0 (0%)
Non-CLABSI	1 (0.67%)

CLABSI: Central line associated blood stream infection

DISCUSSION

This study examined the incidence, clinical and microbiological characteristics of the development of catheter-related infections at a tertiary health care centre. Of the 150 patients, 40 (26.7%) developed a bloodstream infection 4-5 days after CVC insertion. The age group 50 to 60 years old had the highest number of CLABSI cases.[10] In our study, catheter colonisation occurred at a rate of 30% (45). The incidence of catheter colonisation in various other studies ranged from 36% to 70%.[11,12] which was co related to our study. Gram-positive Cocci colonised the catheters the most (17.78%), followed by *Klebsiella pneumoniae*12 (26.67%), *Escherichia coli* 8 (17.78%), *Acinetobacter baumanii* 4 (8.89%), and *Pseudomonas aeruginosa* 4 (8.89%). Gram-positive cocci were the most predominant colonisers of central lines, as said in other research.[13,14] Among the 150 cases, the most common site for central line catheter insertion was subclavian (50%), followed by jugular (40%), and femoral (10%). Out of 40 cases of CLABSI, the highest percentage of infection was discovered in the femoral catheter (80%),[15-17] followed by the jugular catheter (60%) and the subclavian catheter (30%), with a p-value of <0.0031, which was statistically significant and was calculated by the Chi-square test. The occurrence of CLABSI in different site reported by YazanHddadin et al.[18] was related to our study.

In our observation, the CLABSI rate per 1000 days on the central line was 7.8, which was consistent with SZ Bukhari et al. benchmark of 6.8.[18] Fluctuation in the rates of CLABSI could be

Table 8. C LABSI rate in different catheter sites

Site	Overall No. of Patients (n = 150)	No. of blood streams associated with catheters infection cases (n = 40)	P-value
Jugular	60	24 (60%)	<0.0031
Femoral	50	32 (80%)	<0.0031
Subclavian	40	12 (30%)	<0.0031

P value by Chi-square test, statistically significant

attributed to differences in methods employed for blood culture (manual or automated), volume of blood used (5 or 10 ml), number of blood cultures taken (2 or 3 sets), and the lack of clinical indications (variations in clinical signs and symptoms of BSI), eventually increasing the proportion of negative results.[19] Besides, the sample size, nature of patients, design of study, geographical locations, blood culturing rates as well as infection control strategies followed in different countries might have also contributed.[20-22] Above all, infections caused by anaerobes and other etiological agents would had add to this disparity, with respect to the rate of isolation of cultures.[23] When calculating the incidence density of CLABSIs, the device associated infection guidelines of National Healthcare Safety network (NHSN)[24] endorse that we take "central-line days" as the denominator for the calculation. "Central line days" were calculated using a day-by-day count of patients on a central line who were admitted to a healthcare facility. This adjusts the risk of CLABSI with respect to the duration that the central line was in place.

Gram-negative bacteria were the most common isolates in our study, with 27 (67.5%), followed by gram-positive bacteria 13 (32.5%), which correlated with Aneta Guzeket al's study.[25-27] whereas gram-positive cocci were the most common pathogens causing CLABSI in the Zeng C et al. study.[28]

Among the gram-negative bacteria, carbapenemase-producing strains included *Klebsiella pneumoniae* (40%), *Escherichia coli* (62.5%), *Acinetobacter baumanii* (40%) and *Pseudomonas aeruginosa* (75%)which is co relating with other study Montrucchio, G et al study.[29,30] While 90% of *Klebsiella pneumoniae,* 75% of *Escherichia coli,* and 100% of *Acinetobacter baumanii* were ESBL producers, All gram-negative bacteria were sensitive to polymyxin Bwhich is co relating with other studyKhodare A et al.[31-33]

Among the gram-positive cocci isolates, 66.67% of staphylococci were methicillin-resistant Staphylococcus aureus (MRSA) and 71.5% were methicillin-resistant coagulase-negative staphylococci (MR-CoNS). MRSA and MR-CoNS were both susceptible to vancomycin and linezolide; similar findings were reported in different studies.[33]

Out of 40 cases of CLABSI, three patients died: one from renal failure, one from sepsis with multi-organ disorder syndrome (MODS), and two from chronic obstructive pulmonary disease.

The presence of such a resistant strain in our hospitals has grave implications. It is time to establish antibiotic surveillance systems, with each country having its own antibiotic policy and adhering to good infection control practices, including hand hygiene.[34] The colonisation of the catheter with organisms and the production of biofilm play an important role in the development of CLABSI-associated septicaemia and multi-organ failure.[35] Thereby, both central line insertion and maintenance bundle have to be followed strictly to reduce the CLABSI in intensive care units.[36,37]

Active participation of clinicians in the early diagnosis of sepsis and proper collection of samples at an appropriate time for the early diagnosis of sepsis will thereby decrease morbidity and mortality associated with CLABSI.[38,39] More emphasis on teaching and education of medical and paramedical staff regarding the insertion and maintenance bundle for the central line, catheter hub care and after-wound care aids

in the prevention of catheter colonisation and thus reduces CLABSI. Adequate hand hygiene is the most important preventive step for the transmission of multidrug-resistant (MDR) organisms among patients with central lines.[40-42]

Limitations

Due to the small sample size confined to one hospital, our study's ability to generalise current findings was limited. As a result, our study recommended that the study be replicated on a larger probability sample from different geographical locations.

ACKNOWLEDGMENTS

The authors would like to thank all critical care nursing staff and infection control staff at our hospital.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

AUTHORS' CONTRIBUTION

Both authors listed have made a substantial, direct and intellectual contribution to the work, and approved it for publication.

FUNDING

None.

DATA AVAILABILITY

All datasets generated or analyzed during this study are included in the manuscript.

ETHICS STATEMENT

Not applicable.

REFERENCES

1. Alrebish SA, Yusufoglu HS, Alotibi RF, Abdulkhalik NS, Ahmed NJ, Khan AH. Epidemiology of Healthcare-Associated Infections and Adherence to the HAI Prevention Strategies. *Healthcare*. 2022;26;11(1):63. doi: 10.3390/healthcare11010063
2. Ling ML, Apisarnthanarak A, Jaggi N, et al. APSIC guide for prevention of Central Line Associated Bloodstream Infections (CLABSI). *Antimicrob Resist Infect Control.* 2016;5:16. doi: 10.1186/s13756-016-0116-5
3. Huerta LE, Nelson GE, Stewart TG, Rice TW. Factors associated with recurrence and mortality in central line-associated bloodstream infections: a retrospective cohort study. *Crit Care.* 2018;22(1):266. doi: 10.1186/s13054-018-2206-7
4. Doern GV, Carroll KC, Diekema DJ, et al. Practical Guidance for Clinical Microbiology Laboratories: Comprehensive Update on the Problem of Blood Culture Contamination and a Discussion of Methods for Addressing the Problem. *Clin Microbiol Rev.* 2019;33(1):e00009-19. doi: 10.1128/CMR.00009-19
5. H Kitamura, Y Kubota, S Komukai, et al. Venue of catheter insertion does not significantly impact the event of central line-associated bloodstream infection in patients with haematological diseases. *Infection Prevention in Practice,* 2020; 2(2). doi: 10.1016/j.infpip.2020.100050
6. Kochanowicz JF, Nowicka A, Al-Saad SR, Karbowski LM, Gadzinowski J, Szpecht D. Catheter-related bloodstream infections in infants hospitalized in neonatal intensive care units: a single center study. *Sci Rep.* 2022;11(1):13679. doi: 10.1038/s41598-022-17820-w
7. Padmaja K, Sudhaharan S, Vemu L, Teja VD. Early Identification and Antimicrobial Susceptibility Testing of Short versus Standard Incubated Blood Cultures from a Tertiary Care Centre in Southern India. *J Clin Diagn Res.* 2022;16(2):DC20-DC24 doi: 10.7860/JCDR/2022/52679.16004
8. Clinical and Lboratory Standard Institute CLSI Performance standards for Antimicrobial susceptibility testing M100 32nd edition. 2022.
9. Kuan-Yin Lin, Aristine Cheng, Yu-Ching Chang, Mei-Chuan Hung, Jann-Tay Wang, Wang-Huei Sheng, Po-Ren Hseuh, Yee-Chun Chen, Shan-Chwen Chang, Central line-associated bloodstream infections among critically-ill patients in the era of bundle care. *Journal of Microbiology, Immunology and Infection*, 2017; 50(3): 339-348.
10. Sachan H, Manu J, Monika A. Effectiveness of education intervention on nurse's knowledge regarding the prevention of central line-associated bloodstream infection in the intensive care and haemodialysis units in selected hospitals, Kanpur. *Indian Journal of Continuing Nursing Education.* 2022;23(2):196-200. doi: 10.4103/ijcn.ijcn_81_22
11. Pitiriga V, Kanellopoulos P, Bakalis I, et al. Central venous catheter-related bloodstream infection and colonization: the impact of insertion site and distribution of multidrug-resistant pathogens. *Antimicrob Resist Infect Control.* 2020;9(1):189. doi: 10.1186/s13756-020-00851-1
12. Raad I, Darouiche R, Dupuis J, et al. Central venous catheters coated with minocycline and rifampin for the prevention of catheter-related colonization and bloodstream infections. A randomized, double-blind trial. The Texas Medical Center Catheter Study Group. *Ann Intern Med.* 1997;127(4):267-274. doi: 10.7326/0003-4819-127-4-199708150-00002
13. Duyu M, Karakaya Z, Yazici P, et al. Comparison of chlorhexidine impregnated dressing and standard dressing for the prevention of central-line associated blood stream infection and colonization in critically ill pediatric patients: A randomized controlled trial. *Pediatr Int.* 2022;64(1):e15011. doi: 10.1111/

ped.15011
14. He Y, Zhao H, Wei Y, Gan X, Ling Y, Ying Y. Retrospective Analysis of Microbial Colonization Patterns in Central Venous Catheters, 2013-2017. *J Healthc Eng.* 2019;8632701. doi: 10.1155/2019/8632701
15. Toor H, Farr S, Savla P, Kashyap S, Wang S, Miulli DE. Prevalence of Central Line-Associated Bloodstream Infections (CLABSI) in Intensive Care and Medical-Surgical Units. *Cureus*. 2022;14(3):e22809. doi: 10.7759/cureus.22809
16. Haddadin Y, Annamaraju P, Regunath H. Central Line Associated Blood Stream Infections. In: StatPearls. StatPearls Publishing, Treasure Island (FL); 2022. PMID: 28613641
17. Almahmoud RS. Assessment knowledge and practices of central line insertion and maintenance in adult intensive care units at a tertiary care hospital in Saudi Arabia. *J Infect Public Health.* 2020. doi: 10.1016/j.jiph.2020.07.009
18. Bukhari S, Banjar A, Baghdadi S, Baltow B, Ashshi A, Hussain W. Central line associated blood stream infection rate after intervention and comparing outcome with national healthcare safety network and international nosocomial infection control consortium data. *Ann Med Health Sci Res.* 2014;4(5):682-686. doi: 10.4103/2141-9248.141499
19. Birru M, Woldemariam M, Manilal A, et al. Bacterial profile, antimicrobial susceptibility patterns, and associated factors among bloodstream infection suspected patients attending Arba Minch General Hospital, Ethiopia. *Sci Rep.* 2021;11(1):15882. doi: 10.1038/s41598-021-95314-x
20. Blot K, Hammami N, Blot S, et al. Gram-negative central line-associated bloodstream infection incidence peak during the summer: a national seasonality cohort study. *Sci Rep.* 2022;12(1):5202. doi: 10.1038/s41598-022-08973-9
21. Boll B, Schalk E, Buchheidt D, et al. Central venous catheter-related infections in hematology and oncology: 2020 updated guidelines on diagnosis, management, and prevention by the Infectious Diseases Working Party (AGIHO) of the German Society of Hematology and Medical Oncology (DGHO). *Ann Hematol.* 2021;100(1):239-259. doi: 10.1007/s00277-020-04286-x
22. Pitiriga V, Bakalis J, Kampos E, Kanellopoulos P, Saroglou G, Tsakris A. Duration of central venous catheter placement and central line-associated bloodstream infections after the adoption of prevention bundles: a two-year retrospective study. *Antimicrob Resist Infect Control.* 2022;11(1):96. doi: 10.1186/s13756-022-01131-w
23. Niederman MS, Baron RM, Bouadma L, et al. Initial antimicrobial management of sepsis. *Crit Care.* 2021;25:307. doi: 10.1186/s13054-021-03736-w
24. Bloodstream Infection Event (Central Line-Associated Bloodstream Infection and Non-central Line Associated Bloodstream Infection) National Healthcare Safety network Device associated Module. 2023. https://www.cdc.gov>nhsn>pdfs>pscmanual
25. Guzek A, Rybicki Z, Wozniak-Kosek A, Tomaszewski D. Bloodstream Infections in the Intensive Care Unit: a Single-Center Retrospective Bacteriological Analysis Between 2007 and 2019. *Pol J Microbiol.* 2022;71(2):263-277. doi: 10.33073/pjm-2022-025
26. Al-Khawaja S, Saeed NK, Al-Khawaja S, Azzam N, Al-Biltagi M. Trends of central line-associated bloodstream infections in the intensive care unit in the Kingdom of Bahrain: Four years' experience. *World J Crit Care Med.* 2021;10(5):220-231. doi: 10.5492/wjccm.v10.i5.220
27. Khodare A, Kale P, Pindi G, Joy L, Khillan V. Incidence, Microbiological Profile, and Impact of Preventive Measures on Central Line-associated Bloodstream Infection in Liver Care Intensive Care Unit. *Indian J Crit Care Med.* 2020;24(1):17-22. doi: 10.5005/jp-journals-10071-23325
28. Zeng C, Wu A, Li L, Jia H. Multi-center prospective study on central line-associated bloodstream infections in 79 ICUs of China. *BMC Infect Dis.* 2021;21(1):1208. doi: 10.1186/s12879-021-06871-5
29. Montrucchio G, Costamagna A, Pierani T, et al. Bloodstream Infections Caused by Carbapenem-Resistant Pathogens in Intensive Care Units: Risk Factors Analysis and Proposal of a Prognostic Score. *Pathogens*. 2022;11(7):718. doi: 10.3390/pathogens11070718
30. de Carvalho Hessel Dias VM, Tuon F, de Jesus Capelo P, Telles JP, Fortaleza CMCB, Baena CP. Trend analysis of carbapenem-resistant Gram-negative bacteria and antimicrobial consumption in the post-COVID-19 era: an extra challenge for healthcare institutions *J Hosp Infect.* 2022;120:43-47. doi: 10.1016/j.jhin.2021.11.011
31. Kumar S, Sen P, Gaind R, et al. Prospective surveillance of device-associated health care-associated infection in an intensive care unit of a tertiary care hospital in New Delhi, India. *Am J Infect Control.* 2018;46(2):202-206. doi: 10.1016/j.ajic.2017.08.037
32. Amanati A, Sajedianfard S, Khajeh S, et al. Bloodstream infections in adult patients with malignancy, epidemiology, microbiology, and risk factors associated with mortality and multi-drug resistance. *BMC Infect Dis.* 2021;21(1):636. doi: 10.1186/s12879-021-06243-z
33. US Noble, J Rangineni, R Nukanboina et al. A study of microbiological profile and its antimicrobial susceptibility patterns related to central line-associated bloodstream infections in respiratory intensive care unit in a tertiary care hospital. Journal of Clinical and Scientific Research. 2020; 9(1): 25-30. doi: 10.4103/JCSR.JCSR_18_19
34. Buetti N, Marschall J, Drees M, et al. Strategies to prevent central line-associated bloodstream infections in acute-care hospitals: 2022 Update. *Infect Control Hosp Epidemiol.* 2022;43(5):553-569. doi: 10.1017/ice.2022.87
35. Cho HJ, Cho HK. Central line-associated bloodstream infections in neonates. *Korean J Pediatr*. 2019;62(3):79-84. doi: 10.3345/kjp.2018.07003
36. Beville ASM, Heipel D, Vanhoozer G, et al. Reducing Central Line Associated Bloodstream Infections (CLABSIs) by Reducing Central Line Days. *Curr Infect Dis Rep.* 2021;23. doi: 10.1007/s11908-021-00767-w
37. Gupta P, Thomas M, Patel A, et al. Bundle approach used

to achieve zero central line-associated bloodstream infections in an adult coronary intensive care unit. *BMJ Open Qual.* 2021;10(1):e001200. doi: 10.1136/bmjoq-2020-001200

38. Rahmani K, Garikipati A, Barnes G, et al. Early prediction of central line associated bloodstream infection using machine learning. *Am J Infect Control,.* 2022;50(4):440-445. doi: 10.1016/j.ajic.2021.08.017
39. Myatra SN. Improving Hand Hygiene Practices to Reduce CLABSI Rates: Nurses Education Integral for Success. *Indian J Crit Care Med.* 2019;23(7):291-293. doi: 10.5005/jp-journals-10071-23200
40. Mostafa FA, Alnafee K, Al Shanqiti K, Sabah N, Alshuhri S, Badawi D. Reducing Central-Line-Associated Bloodstream Infections (CLABSI): An Improvement Project in a Specialized Tertiary Hospital. *Global Journal on Quality and Safety in Healthcare.* 2022;5(4):84-92. doi: 10.36401/JQSH-22-4
41. Acharya R, Bedanta Mishra S, Ipsita S, Azim A. Impact of Nursing Education on CLABSI Rates: An Experience from a Tertiary Care Hospital in Eastern India. *Indian J Crit Care Med.* 2019;23(7):316-319. doi: 10.5005/jp-journals-10071-23205
42. Hussain AS, Ahmed AM, Arbab S, et al. CLABSI reduction using evidence based interventions and nurse empowerment: a quality improvement initiative from a tertiary care NICU. *Arch Dis Child.* 2021;106(4):394-400.. doi: 10.1136/archdischild-2019-318779