Investigation of the Frequency and Antimicrobial Susceptibility Patterns of Bacteria Isolated from Blood Cultures in Khorramabad in 2018

Running title: Antibiotic sensitivity of bacteria isolated from blood cultures

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Abstract

Background: The widespread increase in the prevalence of antibiotic resistance in bacteria is considered one of the biggest problems in the global health and treatment system today. Therefore, this study was conducted to investigate the prevalence and antibiotic resistance pattern of bacteria isolated from blood cultures at Shahid Rahimi Hospital in Khorramabad in 2018.

Methods: This cross-sectional study investigated, blood cultures of patients admitted to Shahid Rahimi Hospital from June to December 2018 were investigated. The disc diffusion method was used according to CLSI instructions and the data were analyzed using SPSS software.

Results: Out of a total of 2591 blood culture samples, 247 blood culture samples were positive. The highest frequency was related to the emergency department (62%) and ICU (23%), and the lowest frequency was related to the children's department (2.4%). Among the tested samples, 28% were Gram-negative bacilli and 72% were Gram-positive cocci. The most common Gram-negative and Gram-positive bacteria were *Escherichia coli* (38%) and *Staphylococcus epidermidis* (54.2%), respectively. Among Gram-negative bacteria, the highest level of resistance was seen in *Acinetobacter baumannii* strains, which showed resistance to all antibiotics. Among Gram-positive bacteria, the highest resistance of *Streptococcus* group D strains to the antibiotic erythromycin (92%) was reported.

Conclusion: The prevalence of antibiotic resistance in common microorganisms isolated from blood cultures in different departments is worrying, and choosing an effective drug to eliminate these bacteria by performing accurate laboratory tests is of particular importance.

Keywords: Blood culture; Antibiotic sensitivity; Bacteria

Introduction

The presence of bacteria in the blood (bacteremia) is crusial and can lead to sever consequences and even death. Appropriate and prompt treatment of this infection is essential because it significantly reduces mortality (1). For the laboratory diagnosis of bacteremia, the most common method is the culture and isolation of bacteria, which is followed by the antibiotic sensitivity test of the isolated bacteria, which helps a lot in choosing the appropriate antimicrobial drug to treat the patient. The range of microorganisms that cause blood infection is different in different countries and also often varies from one treatment center to another within a country region or city. However, in most cases, gram-negative bacteria contribute more to causing infections than Gram-positive ones, and nowadays sepsis reported from gram-negative bacteria is increasing, especially in Asian countries (2, 3). Common bacteria isolated from blood infections are Pseudomonas aeruginosa, Klebsiella pneumoniae, Acinetobacter, Escherichia coli, Enterobacter, coagulase negative Staphylococcus and Staphylococcus aureus (4). Investigation of antibiotic resistance is based on dilution and diffusion. The basis of the agar diffusion disc method is diffusion, which shows the resistance of bacteria to antibiotics. Relying on the data obtained from the results of determination of antibiotic sensitivity and resistance, which is different according to the isolated bacterial species, it helps the doctors in choosing the appropriate antibiotic and the treatment process of the patients (5).

Due to the increase in the use of antibiotics, a large number of bacteria are resistant to antibiotics and the process of treating blood infections has become a challenge (6, 7). Research has shown that blood infection caused by antibiotic-resistant bacteria causes higher mortality, long-term hospitalization, and higher costs than antibiotic-sensitive bacteria (8). Some studies showed that the most common bacterial causes of blood infections are *S. aureus* and *P. aeruginosa* (9). In studies in Iran, it was also reported that the highest frequency of microorganisms isolated from patients with acquired blood infections is caused by hospital infections related to *E. coli* and *K.pneumoniae*. Also, imipenem was recognized as the most effective antibiotic against isolated strains (10).

This study aimed to investigate the prevalence and antibiotic resistance patterns of bacterial strains in the blood culture samples from Shahid Rahimi Hospital, in Khoramabad City (South West of Iran).

Methods

This study was designed as a cross-sectional study. After obtaining the necessary permissions from the honorable Vice President of Research at Lorestan University of Medical Sciences, the information recorded in this study was conducted in Shahid Rahimi Hospital in Khorramabad for 7 months from June to December 2018. The sampling method used was consecutive and available.

Cultivation of samples and identification of bacteria

Initially, the samples were cultured on blood agar, chocolate agar, and Eosin Methylene Blue (EMB) agar cultures at 24, 48, and 72 hours and on the seventh day after being kept in the incubator, and after incubation at 35 ±2°C, the Gram staining was prepared from the resulting colonies. Standard microbial tests including oxidase, catalase, DNase, coagulase, OF fermentation, citrate consumption, sugars, indole, motion, and Methy Red and Voges-Prauskauer (MR-VP) tests were used to determine the species of bacteria.

Antimicrobial susceptibility testing

To evaluate the level of resistance of Gram-negative bacteria isolated from blood culture according to the guidelines of the Clinical and Laboratory Standards Institute (CLSI) table and by the agar

disk diffusion method, using Mueller Hinton Agar culture medium method (Merck, Germany) and antibiotic discs (PADTAN TEB, Iran) was used (11). For Gram-negative bacteria, Cefoxitin 30 μg, Cefepime 30 μg, Ceftriaxone 30 μg, Cefotaxime 30 μg, Ciprofloxacin 5 μg, Amikacin 30 μg, Gentamycin 10 μg and Tetracycline 30 μg were tested. For Gram-positive bacteria, Cephalexin 30 μg, Penicillin10 μg, Ciprofloxacin 5 μg, Levofloxacin 30 μg, Gentamicin 10 μg, Tetracycline 30 μg, Clindamycin 2 μg, and Erythromycin 15 μg were used (12).

Data analysis

SPSS software version 20 was used for statistical analysis and to check the frequency of the studied variables. Frequency ratios and percentages as well as the mean and standard deviation of the data were used to describe the information and the results were presented in the form of statistical tables and graphs. Chi square test (χ^2) was used to determine relationship between dependent and independent variable. The significance level was considered less than 0.05.

Results

In the present study, 314 positive blood culture samples were isolated from a total of 2591 blood culture samples. Of these, 2 cases of fungi and 37 cases of Gram-positive bacillus (*Bacillus* and *Corynebacterium*) were excluded from the study as cases of blood culture contamination, as well as samples whose information was incomplete, and finally, 247 positive blood culture samples, were included in the study. According to the results, most bacteria isolated from the positive blood culture samples were related to adults over 60 years old (40.1 %) in 99 cases and the least related to the age group between 11-20 years old (2.8 %) was 7 cases. 141 (57.1%) and 106 (42.9%) were isolated from men and women, respectively. The highest frequency of bacteria was reported in the emergency department (62 %), and ICU (23 %), and the lowest in the pediatric department (2.4 %). The distribution and frequency of positive blood culture samples by section are shown in Table 1.

Table 1- Distribution and frequency of positive blood culture samples by department

Sampling location unit	Relative frequency (%)	Absolute frequency (%)	
Emergency	62 153		
ICU	23	57	
Internal	7.3	18	
Surgery	3.3	8	
Children	2.4	6	
Other	2	5	
Total	100	247	

Among the 247-blood culture-positive samples, 70 samples (28%) were gram-negative bacilli and 177 samples (72%) were gram-positive cocci. The abundance of Gram-positive and Gram-negative bacteria in blood cultures based on different variables is shown in Table 2.

Table 2- Frequency of Gram-positive and Gram-negative bacteria in blood cultures based on different variables

X7 ' 1 1	Property	Gram-negative	Gram-positive	Total	P-value
Variable		bacilli	cocci	Number	
		Number (%)	Number (%)	(%)	
Age categories	1 >	9(9.12)	47(6.26)	56(22.7)	
	1-10	2(9.2)	15(5.8)	17(6.9)	> ,
	20-11	0(0)	7(4)	7(2.8)	
	30-21	1(4.1)	7(4)	8(3.2)	< 0.006
	40-31	8(2.6)	11(4.11)	19(7.7)	
	60-41	13(8.15)	28(6.18)	41(16.6)	
	60 >	35(37)	62(9.52)	99(40.1)	
Gender	Male	49(57.1)	101(57)	141(57.1)	< 0.2
	Female	30(42.9)	76(43)	106(42.9)	
	Emergency	30(48)	105(70)	153(100)	
Sampling	ICU	13(23)	44(77)	57(100)	
	Internal	6(34)	12(66)	18(100)	< 0.002
location unit	Surgery	1(13)	7(87)	8(100)	\ 0.002
	Children	1(17)	5(83)	6(100)	
	Other	1(20)	4(80)	5(100)	

The abundance of bacteria isolated from blood cultures

The highest frequency of Gram-positive bacteria was related to *S.epidermidis* 96 (54%) and the lowest was related to *Micrococcus* spp. 9 (5%). Among the Gram-negative bacteria isolated, the highest frequency was *E. coli* 27 (38.5%) and the lowest was *A.baumannii* 3 (2.4%) (Figure 1).

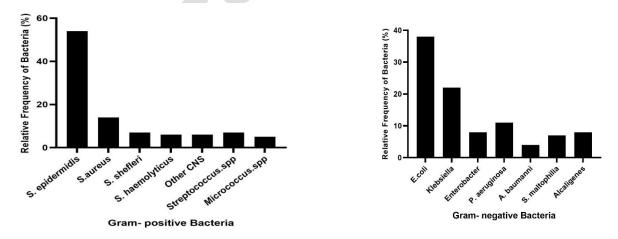


Figure 1. Abundance of Gram-positive and Gram-negative bacteria isolated from blood cultures

Results of antibiotic sensitivity and resistance patterns

In the present study, the highest and lowest resistance levels of E. coli were reported to be 55% and 1% amikacin, respectively. The highest and lowest resistance of K. pneumoniae to cefoxitin, ceftriaxone, ciprofloxacin (62%), and amikacin 12% were reported. The highest and lowest levels of resistance of *Enterobacter aerogenous* were reported to cefoxitin, ceftriaxone, cefotaxime, and ciprofloxacin (40%), and resistance to cefepime, amikacin, gentamicin, and tetracycline (20%). The most resistant of P. aeruginosa strains to tetracycline (75%), but none of the isolates were resistant to amikacin and gentamicin. A.baumannii strains were 100% resistant to cefoxitin, cefepime, ceftriaxone, cefotaxime, ciprofloxacin, amikacin, gentamicin, and tetracycline. Also, Stenotrophomonas maltophilia were 100% resistant to cefoxitin, cefepime, and ceftriaxone, and no resistance was reported to cefotaxime, amikacin, and gentamicin. Alkaligenes strains also showed resistance to ceftriaxone (83%) and the least resistance to tetracycline (16%). The highest and lowest levels of resistance of Staphylococcus aureus strains were erythromycin (72%) and gentamicin (4%). The highest and lowest levels of resistance of Staphylococcus epidermis were clindamycin (70%) and gentamicin (30%). The highest and lowest levels of resistance of Staphylococcus schleiferi to clindamycin (66%) and penicillin (1%) were reported. The highest and lowest levels of resistance in Staphylococcus hemolyticus were observed to erythromycin (54%) and gentamicin and tetracycline (18). Group D streptococcus gram-positive cocci showed the highest level of resistance to erythromycin (92%) and the lowest level to gentamicin (30%). Micrococcal strains had the highest resistance to erythromycin (66%) and no resistance was reported to ciprofloxacin, cephalexin, levofloxacin, and clindamycin (Figure 2).

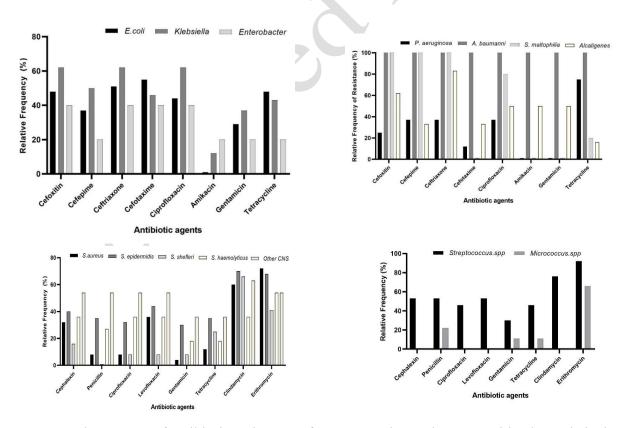


Figure 2. The amount of antibiotic resistance of gram-negative and gram-positive bacteria isolated from blood cultures of patients

Discussion

Antibiotic resistance is a phenomenon that can be seen more or less in different parts of the world (13, 14). In general, bacteria may be naturally resistant to antibiotics or may have acquired resistance through mutation or acquisition of resistance genes from other bacteria, so the level of resistance in bacteria in different studies is different. These changes change even in different years, depending on the factors that cause infection (15-18). In developed countries, Gram-positive bacteria are the most common cause of hospital bacteremia (19). Determining the organisms that cause blood infections, especially the hospital type, and quick and timely diagnosis of bacteremia are important in order to reduce mortality and treatment costs.

In our study we found that the frequency of bacteria in the age group over 60 years was higher (P<0.05), which is probably due to the weakness of the immune system of these people due to old age. Also, the frequency of bacteria in the ICU department was higher than in other departments. P < 0.05). Based on the findings, it has been determined that although only 5% of hospital beds belong to the ICU and less than 10% of all patients are treated in this department, more than 25-33% of hospital infections ICU are dedicated, and the use of mechanical ventilation, urinary catheters, and intravenous instruments are among the major factors that cause it (20, 21). In our study, the frequency of gram-positive cocci isolated from positive blood culture samples was reported in 177 samples (72%) and gram-negative bacilli in 70 samples (28%). The most grampositive cocci isolated from coagulase-negative staphylococci was 107 (60%), and among the coagulase-negative staphylococci, the most abundant isolated organism was S. epidermis (54%). In the study of Mahmoudi et al., which examined 195 hospitalized patients with positive blood cultures in 1991-93, the highest frequency was related to infectious departments and children, respectively, and the most isolated organism was related to coagulase-negative staphylococci, which was responsible for 60 (30.77 %) were reported (22). In the study of Mohammadi et al. in Sanandaj (2015), which was conducted on 180 positive blood culture samples that were isolated during one year, the highest frequency related to S. epidermidis was reported 51.11(11). by Tabatabai (2008), the most common bacteria among 104 positive blood cultures were coagulasenegative staphylococci (40.4%), followed by coagulase-positive staphylococcus (3.17%) (23). In many studies, S. epidermidis has been proposed as the most common cause of bacteremia, which is consistent with our study. Based on the research, about 50% of bacteremia is caused by grampositive cocci, and its prevalence is estimated at 700,000 to 330,000 cases annually in the United States. It can be the increase in the prevalence of bacteremia caused by gram-positive cocci in the last two decades is due to several factors such as the increase in the use of invasive diagnostic methods, which strengthen bacteria in body tissues due to penetration into sterile areas without colonization (24).

In a recent study, *E. coli* (38%) was the most common gram-negative bacillus isolated from blood cultures. In the study of Vaez et al. in Iran, *E. coli* (29%) was reported as the most common gramnegative bacillus causing bacteremia, which is consistent with our study. Also, in Iran, Mohammadi Mehr et al reported the most abundant microorganisms isolated from patients with a blood infection caused by hospital infection, respectively, *E. coli* (35.6%) 9 and *K.pneumoniae* (24.7%) (21). Hsueh et al. in Taiwan (9), and Kihanian et al. in Rasht (25) reported that the most common gram-negative bacillus causing blood infection was *P. aeruginosa*. The health level of the region, the time of the study, geographical differences, and the restriction of arbitrary use of antibiotics are also factors of the difference in the results of the resistance level in bacteria in different geographical locations (26). In the present study, after the emergency, in the ICU, the highest rate of positive blood cultures was found. In our study, the highest and lowest resistance

of S. aureus was to erythromycin (72%) and gentamicin (4%). The highest and lowest resistance in E. coli isolates were cefotaxime (55%) and amikacin (1%). Among 107 dialysis patients in Tabriz, Akbarzadeh et al. isolated 50 Staphylococcus spp. and reported the highest sensitivity to gentamicin (80%) and ciprofloxacin (90%) (27). In the study of Nouri et al. in Hamedan in blood infections, the highest level of resistance of bacteria isolated from blood culture was related to A. baumannii, S. epidermidis, and P.aeruginosa, respectively(21). Each of the bacteria shows different sensitivity to different antibiotics in different regions and at different times, and the treatment of bacterial infections is completely related to the ability of bacteria to develop resistance to antimicrobial agents. Therefore, by determining the prevalence of microbial agents that cause blood infection and the pattern of antibiotic resistance annually, it is possible to help doctors and laboratory technicians to choose effective antibiotics for the purpose of antibiogram testing, because choosing effective antibiotics for treatment is necessary and leads to It reduces treatment costs (28, 29). It is also suggested that due to the high resistance of some isolated bacteria to antibiotics, regional and even national planning should be done to remove some antibiotics from the list of consumed antibiotics in order to witness a reduction in the rate of antibiotic resistance and better effective decision-making.

Conclusion

The prevalence of antibiotic resistance in bacteria isolated from blood cultures in the present study is significant. Choosing an effective and accurate antibiotic for treatment can have a significant impact on reducing costs and reducing the length of the treatment period.

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Ethics approvals

The current research project was approved by the Research Ethics Committee of Lorestan University of Medical Sciences and with the code of ethics IR.LUMS.REC.1399.340.

Conflict of interest

The authors declare no conflict of interest, financial or otherwise.

Author contributions

Shakib P; Writing the article Data review, Halimi Sh; Data analysis, Mehrabnejad E; Data collection, Rezaei F; Scientific advisor, Delfani S; Research design and Project Management.

Data availability statement

Data supporting our study findings are available from the corresponding author upon reasonable request.

References

- 1. Holmes CL, Anderson MT, Mobley HL, Bachman M. Pathogenesis of Gram-negative bacteremia. Clin Microbiol Rev. 2021;34(2):e00234-20.
- 2. Huttunen R, Aittoniemi J. New concepts in the pathogenesis, diagnosis, and treatment of bacteremia and sepsis. J Infect. 2011;63(6):407-19.
- 3. Lodise TP, McKinnon PS, Swiderski L, Rybak M. Outcomes analysis of delayed antibiotic treatment for hospital-acquired Staphylococcus aureus bacteremia. Clin Infect Dis. 2003;36(11):1418-23.
- 4. Reimer LG, Wilson ML, Weinstein MP. Update on detection of bacteremia and fungemia. Clin Microbiol Rev. 1997;10(3):444-65.
- 5. Erfani Y, Safdari R, Chobineh H, Mir Salehian A, Rasti A, Eynollahi N, et al. Comparison of E.test and disk diffusion agar in detection of antibiotic susceptibility of *E. coli* Isolated from patients with urinary tract infection in Tehran Shariati Hospital. Sci J Hamadan Univ Med Sci. 2008;15(2)27-31
- 6. Schöneweck F, Schmitz RP, Rißner F, Scherag A, Löffler B, Pletz MW, et al. The epidemiology of bloodstream infections and antimicrobial susceptibility patterns in Thuringia, Germany: a five-year prospective, state-wide surveillance study (AlertsNet). Antimicrob Resist Infect Control. 2021;10(1):1-9.
- 7. Abebe W, Tegene B, Feleke T, Sharew B. Bacterial bloodstream infections and their antimicrobial susceptibility patterns in children and adults in Ethiopia: a 6-year retrospective study. Clin Lab. 2021;67(11): 453-61.
- 8. Kang C-I, Kim S-H, Park WB, Lee K-D, Kim H-B, Kim E-C, et al. Bloodstream infections caused by antibiotic-resistant gram-negative bacilli: risk factors for mortality and impact of inappropriate initial antimicrobial therapy on outcome. Antimicrob Agents Chemother .2005; 49(2):760-6.
- 9. Hsueh P-R, Chen M-L, Sun C-C, Chen W-H, Pan H-J, Yang L-S, et al. Antimicrobial drug resistance in pathogens causing nosocomial infections at a university hospital in Taiwan, 1981-1999. Emerg Infect Dis. 2002;8(1):63-8.
- 10. Mohammadimehr M, Feizabadi M, Bahadori A. Antibiotic resistance pattern of gram negative bacilli caused nosocomial infections in ICUs in khanevadeh and golestan hospital in Tehran-2007. Ann Mil Health Sci Res. 2011;8(4):283-90.
- 11. Mohammadi B, Ramazanzadeh R, Mohammadi S, Zandi S. Prevalence of isolated bacterial and antibiotic resistant pattern of them in positive blood cultures isolated from patients admitted to different parts of Toohid Hospital of Sanandaj city (2013-2014). Navid No. 2015;18(60):34-41.
- 12. Abebaw A, Tesera H, Belachew T, Mihiretie GD. The bacterial profile and antibiotic susceptibility pattern among patients with suspected bloodstream infections, Gondar, north-west Ethiopia. Pathol Lab Med Int. 2018:1-7.
- 13. Dadgostar P. Antimicrobial resistance: implications and costs. Infect drug resist. 2019:3903-10.
- 14. Marston HD, Dixon DM, Knisely M, Palmore TN, Fauci AS. Resistencia antimicrobiana. JAMA. 2016;316(11):1193-204.
- 15. Ntirenganya C, Manzi O, Muvunyi CM, Ogbuagu O. High prevalence of antimicrobial resistance among common bacterial isolates in a tertiary healthcare facility in Rwanda. Am J Trop Med Hyg. 2015;92(4):865.

- 16. Erb A, Stürmer T, Marre R, Brenner H. Prevalence of antibiotic resistance in Escherichia coli: overview of geographical, temporal, and methodological variations. Eur J Clin Microbiol Infect Dis. 2007;26:83-90.
- 17. Jabbari Shiadeh SM, Pormohammad A, Hashemi A, Lak P. Global prevalence of antibiotic resistance in blood-isolated Enterococcus faecalis and Enterococcus faecium: a systematic review and meta-analysis. Infect Drug Resist. 2019:2713-25.
- 18. Qureshi M, Aziz F. Prevalence of microbial isolates in blood cultures and their antimicrobial susceptibility profiles. Biomedica. 2011;27(2):136-9.
- 19. Dogru A, Sargin F, Çelik M, Sagiroglu AE, Goksel MM, Sayhan H. The rate of device-associated nosocomial infections in a medical surgical intensive care unit of a training and research hospital in Turkey: one-year outcomes. Jpn J Infect Dis. 2010;63(2):95-8.
- 20. Chaudhari DM, Bhavsar HK, Thummar SG, Shah UV. Study of prevalence and antimicrobial susceptibility pattern of organisms isolated from various clinical specimen of the patients admitted in intensive care unit of tertiary care hospital. Natl J Physiol Pharm Pharmacol .2022;13(3):0.
- 21. Nouri F, Kamarehei F, Asghari B, Hazhirkamal M, Abdollahian AR, Taheri M. Prevalence and drug resistance patterns of bacteria isolated from wound and bloodstream nosocomial infections in Hamadan, West of Iran. All Life.2022;15(1):174-82.
- 22. Mahmoudi H, Ghasemi Bassir HR, Hosseini SM, Arabestani MR, Alikhani M. The frequency of bacteria isolated from blood cultures and antibiotic susceptibility patterns among admitted patients in Hospital of Hamedan University of Medical Sciences. Iran J Med Microbiol. 2016;10(4):69-74.
- 23. Tabatabaei S T. Frequency and antimicrobial susceptibility of bacteria isolated from urine, stool, and blood cultures of Rafsanjan University of Medical Sciences laboratories during 2003. J Rafsanjan Univ Med Sci. 2008;7(2):105-12.
- 24. Cyphert EL, Learn GD, Marques DW, Lu CY, von Recum HA. Antibiotic refilling, antimicrobial activity, and mechanical strength of PMMA bone cement composites critically depend on the processing technique. ACS Biomaterials Science and Engineering. 2020;6(7):4024-35.
- 25. Keihanian F, Saeidinia A, Abbasi K, Keihanian F. Epidemiology of antibiotic resistance of blood culture in educational hospitals in Rasht, North of Iran. Infect Drug Resist.2018;11:1723.
- 26. Teferi MY, El-Khatib Z, Alemayehu EA, Adane HT, Andualem AT, Hailesilassie YA, et al. Prevalence and antimicrobial susceptibility level of typhoid fever in Ethiopia: A systematic review and meta-analysis. Prev Med Rep. 2022;25:101670.
- 27. Akbarzadeh Khiavi T, Nahaei M, Rahmati A, Asgharzadeh M. Plasmid profiles and antibiotic resistance of Staphylococcus aureus isolated from nasal carriers in hemodialysis patients in Imam Khomeini hospital of Tabriz. J Ardabil Univ Med Sci. 2007;7(1):7-14.
- 28. De Angelis G, Grossi A, Menchinelli G, Boccia S, Sanguinetti M, Posteraro B, et al. Rapid molecular tests for detection of antimicrobial resistance determinants in Gram-negative organisms from positive blood cultures: a systematic review and meta-analysis. Clin Microbiol Infect. 2020;26(3):271-80.
- 29. Holma T, Torvikoski J, Friberg N, Nevalainen A, Tarkka E, Antikainen J, Martelin JJ. Rapid molecular detection of pathogenic microorganisms and antimicrobial resistance markers in blood cultures: evaluation and utility of the next-generation FilmArray Blood Culture Identification 2 panel. Europ J Clin Microbiol Infect Dis. 2022;1:1-8.