ORIGINAL ARTICLE

A two-year study of microbiological characteristics of intravascular catheter-related bloodstream infections at Razi Hospital, Iran

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ABSTRACT

Objectives: A substantial proportion of healthcare-associated infections are typically associated with devices such as indwelling intravascular devices (arterial and venous catheters), resulting in increased long-term hospitalisation, cost, morbidity, and mortality. This study aimed to determine the microbiological characteristics of bloodstream infection caused by intravascular device catheters in the north of Iran.

Methods: This retrospective study was conducted between 2018 and 2019 on inpatients with catheter-related bloodstream infections. Bacterial isolation and identification were carried out using standard microbiological and biochemical techniques. The disc diffusion method was used to determine antimicrobial susceptibility.

Results: Out of 287 examined catheters, 95 (33.1%) cases were positive for significant bacterial growth. Catheter-related bloodstream infections were most frequently caused by coagulase-negative staphylococci (28.4%), *Staphylococcus aureus* (15.8%), *Klebsiella pneumoniae* (14.7%), and *Pseudomonas aeruginosa* (12.6%). According to antibiotic susceptibility testing, the most effective antibiotics against staphylococci were amikacin, co-trimoxazole, and tetracycline. Meanwhile, 33.3% of *S. aureus* isolates and 56% of coagulase-negative staphylococci were methicillin-resistant. Gram-negative isolates showed a very high rate of antibiotic resistance, even toward the last resorts antibiotics such as carbapenems.

Conclusions: Our study revealed an alarming rate of catheter-associated infection, necessitating implementing a more stringent and effective infection control policy. Additionally, our observations provide critical data for making more targeted empirical antibiotic selections based on the local antibiotic susceptibility pattern.

Key words: Healthcare-associated infection; intravascular catheter-related infections; antibiotic resistance; bacterial infection.

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INTRODUCTION

Nosocomial infections, alternatively referred to as healthcare-associated infections, occur during receiving health care in a hospital or other health care facility where the patient was not admitted (1). Adverse drug reactions, healthcare-associated infections,, and surgical complications are the most frequently encountered adverse events in hospitalised patients (2). More than half of all reported healthcare-associated infections originate in developing countries (3). Bacteria are responsible for most healthcare-associated infections while mycobacterial, viral, fungal, and protozoal agents are less frequently implicated (2).

Staphylococci, a diverse group of *Enterobacteriaceae* and *Pseudomonas* spp. along with *Acinetobacter* spp. are the most common bacteria that cause healthcare-associated infections. These infections account for up to 70% of all ICU infections (2). Pneumonia, urinary tract infection (UTI), and bloodstream infection are the most common types of healthcare-associated infections. Furthermore, surgical site infection, gastroenteritis, and meningitis are also prevalent (2).

A substantial proportion of healthcare-associated infections is typically associated with the use of indwelling intravascular and urinary catheters, which can increase long-term hospitalisation, cost, morbidity, and mortality (4). The method and site of catheter insertion and underlying diseases are the primary risk factors for catheter-related infections (5). Biofilm formation is a common bacterial strategy for survival, which is a critical concern for public health (6).

Colonisation on the tip, internal, or external surfaces of catheters are essential for infection durability, as bacteria associated with biofilms exhibit significantly reduced susceptibility to antibiotic therapy (6). A significant impediment to treating healthcare-associated infections is the global rise in antibiotic-resistant organisms. As a result, applying methods to prevent nosocomial infections is gaining momentum (7).

Monitoring healthcare-associated infections is a vital and primary step in preventing and controlling infection widely accepted worldwide (8). By implementing strategies to prevent catheter-associated infections, health care costs, morbidity, and mortality can be significantly reduced. The purpose of this study was to determine the prevalence, bacterial aetiology, and pattern of antibiotic resistance in intravascular catheter-related infections in northern Iran.

METHODS

Study design and population

We conducted a retrospective study on patients hospitalised with catheter-related bloodstream infections at Razi Hospital, a teaching and rehabilitation facility in northern Iran. The purpose of this study was to evaluate patients admitted to Razi University Hospital with arterial or venous catheterisation in 2018 and 2019. In the absence of other sources of blood stream infection, an episode of catheter-related bloodstream infection was defined as catheters inserted for at least ≥48 hours and with at least one positive culture obtained from a patient with clinical manifestations such as fever or hypotension. The study design was approved by the Ethics Committee of the Guilan University of Medical Sciences (Reg No. IR.GUMS.REC.1398.392) and followed the declaration of Helsinki.

Sample processing and bacterial identification

Each patient's catheter site was cleaned before sampling and the catheter was removed without contacting the skin. The catheter's terminal 5 cm was cut into a sterile container and transferred to the laboratory within one hour. Following that, all catheter tips were transferred to 1 mL tryptic soy broth for culture. Then, 10 µL of bacteria growth in tryptic soy broth was transferred to blood agar, chocolate agar, and MacConkey

agar. The blood agar and MacConkey agar plates were incubated aerobically at 37ºC for 24-48 hours. At 37 ºC, chocolate agar plates were incubated in an atmosphere supplemented with carbon dioxide (a candle jar), and plates with a high level of bacterial growth were chosen for further processing. To identify positive samples standard microbiological and biochemical methods were used to test isolates, including morphological analysis, Gram staining, catalase, oxidase, coagulase tests, sugar fermentation, and other phenotypic biochemical tests.

Antibiotic susceptibility testing

The disc diffusion method was used to determine antimicrobial susceptibility on Mueller-Hinton agar (Merck, Germany) following the Clinical and Laboratory Standards Institute (CLSI) recommendations (9). CLSI recommendations were followed to select antimicrobial discs (Padtan Teb, Iran), control strains, and interpretation of results for each pathogen.

Statistical analysis

For statistical analysis, the SPSS™ software (version 21) was used. The findings are presented in the form of descriptive statistics based on relative frequency. Frequencies and percentages were used to summarise categorical variables, while median and interquartile range (IQR) values were used to describe continuous variables.

RESULTS

During the study period, a total of 287 intravascular catheters (102 in 2019 and 185 in 2020) were removed from hospitalised patients and sent to the laboratory. From the tested catheters, 95 (33.1%) were positive, demonstrating significant bacterial growth. Infected patients' median (IQR) age was 65 (52-73), ranging from 19 to 95.

Catheter-related bloodstream infections were caused by a total of 12 different types of bacteria, with 46 (48.4%) cases caused by Gram-positive bacteria and 49 (51.6%) by Gram-negative bacteria (Table 1). Coagulase-negative staphylococci were the most prevalent bacteria (28.4%), followed by *Staphylococcus aureus* (15.8%), *Klebsiella pneumoniae* (14.7%), and *Pseudomonas aeruginosa* (12.6%).

Tables 2 and 3 illustrate the antibiotic resistance patterns of Gram-positive and Gram-negative bacteria, respectively. Amikacin, co-trimoxazole, and tetracycline were the most effective antibiotics against staphylococci, the most common cause of catheter-related bloodstream infections. Meanwhile, 33.3% of *S. aureus* isolates and 56% of coagulase-negative staphylococci were methicillin resistant. Gram-negative isolates showed a very high rate of antibiotic resistance, even toward the last resorts antibiotics such as carbapenems.

Table 1. Frequency of causative organisms isolated from CRBSIs.

Gram stain	Bacteria type	Frequency	Percent
Gram-positive	Coagulase-negative staphylococci	27	28.4
	Staphylococcus aureus	15	15.8
	Micrococcus spp.	3	3.2
	Enterococcus faecalis	2	2.1
	Streptococcus group D	1	1
Gram-negative	*Klebsiella pneumoniae*	14	14.7
	Pseudomonas aeruginosa	12	12.6
	Acinetobacter baumannii	7	7.4
	Enterobacter cloacae	5	5.3
	Escherichia coli	4	4.2
	Citrobacter spp.	4	4.2
	Stenotrophomonas maltophilia	1	1
Total		95/287	33.1

Table 2. Antibiotic resistance pattern of Gram-positive bacteria*

Antibiotics	CoNS (N = 27) %			*S. aureus* (N = 15) %			*Micrococcus* (N = 3) %			*E. faecalis* (N = 2) %		
	S	I	R	S	I	R	S	I	R	S	I	R
Penicilin	0	0	100	8		92	0	0	100	0	0	100
Ampicilin	-	-	-	-	-	-	-	-	-	50	0	50
Cefoxitin	44	0	56	66.7	0	33.3	-	-	-	-	-	-
Tetracycline	54	0	46	46	0	54	-	-	-	50	0	50
Amikacin	58	0	42	61	8	31	-	-	-	-	-	-
Gentamicin	44	7	48	53	7	40	-	-	-	0	0	100
Clindamycin	27	0	73	33	0	67	0	0	100	-	-	-
Erythromycin	13	0	87	29	0	71	0	0	100	-	-	-
Ciprofloxacin	21	0	79	33	0	67	-	-	-	-	-	-
Co-trimoxazole	54	0	46	64	7	29	-	-	-	0	0	100
Vancomycin	-	-	-	-	-	-	-	-	-	50	0	50

*Results estimated based on the numbers of tested isolates.

Table 3. Antibiotic resistance pattern of Gram-negative bacteria*

Antibiotics	*K. pneumonia* (N = 14) %			*P. aeruginosa* (N = 12) %			*E. cloacae* (N = 5) %			*E. coli* (N = 4) %			*Citrobacter* (N = 4) %			*S. maltophilia* (N = 1) %			*A. baumannii* (N = 7) %		
	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R	S	I	R
Piperacilin	0	0	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Piperacilin-Tazobactam	25	0	75	0	0	100	0	50	50	0	33	67	33	0	67	-	-	-	0	0	100
Cefazolin	0	0	100	-	-	-	0	0	100	0	0	100	-	-	-	-	-	-	-	-	-
Cefoxitin	0	0	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cefotaxime	20	0	80	-	-	-	0	0	100	0	0	100	-	-	-	-	-	-	0	0	100
Ceftazidime	17	0	83	29	0	71	33	0	67	-	-	-	100	0	0	0	0	100	0	0	100
Ceftriaxone	0	0	100	-	-	-	-	-	-	0	0	100	0	0	100	-	-	-	-	-	-
Ceftizoxime	-	-	-	0	0	100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cefepime	22	0	78	0	0	100	0	0	100	0	0	100	33	0	67	-	-	-	0	0	100
Tetracycline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0	0	100
Amikacin	21	0	79	46	0	54	-	-	-	25	0	75	25	0	75	-	-	-	0	29	71
Gentamicin	23	0	77	40	0	60	25	0	75	25	0	75	0	0	100	-	-	-	33	17	50
Ofloxacin	0	0	100	100	0	0	0	0	100	-	-	-	-	-	-	-	-	-	-	-	-
Ciprofloxacin	27	0	73	43	0	57	50	25	25	25	0	75	50	0	50	100	0	0	14	14	71
Meropenem	0	0	100	0	0	100	50	0	50	0	0	100	33	0	67	-	-	-	-	-	-
Imipenem	22	0	78	75	0	25	67	0	33	0	33	67	100	0	0	-	-	-	17	0	83
Co-trimoxazole	18	9	73	-	-	-	60	0	40	25	0	75	25	0	75	100	0	0	25	25	50

*Results estimated based on the numbers of tested isolates.

DISCUSSION

Catheter-related bloodstream infections are widely regarded as one of the most severe health system challenges of the modern era, owing mainly to the increased use of venous catheters in recent years (5,10). We examined the prevalence and aetiology of catheter-related bloodstream infections in hospitalised patients in this study. Out of 287 studied catheters, 33.1% had positive culture, indicating the presence of catheter-related bloodstream infections. Our study's prevalence of catheter-associated infections (33.1%) is higher than a recent estimate of 18.79% based on Iranian national nosocomial infection surveillance data (11). Regional variation in HCAI prevalence could be explained by differences in geographical distribution, infection control policies, studied population, and catheterisation-related factors. Similarly, there is a similar degree of heterogeneity in reported catheter-related bloodstream infections incidence/prevalence worldwide (12-16).

Gram-positive and Gram-negative isolates occurred at nearly the same rate in this study. Gram-positive cocci, particularly staphylococci, are generally considered the most common cause of catheter-related bloodstream infections (17). However, some reports indicate that Gram-negative organisms are increasing, mainly due to their ability to acquire multidrug resistance mechanisms (12,13,18).

According to recent estimates the rate of methicillin-resistant *Staphylococcus aureus* (MRSA) infection in our study (33%) was higher than the overall prevalence (21.3%) of MRSA in a national blood sample (19). In comparison, our methicillin-resistant coagulase-negative staphylococci rate (56%) was lower than the national estimates (73.9%) (20). Despite the increasing prevalence of drug-resistant strains, several studies supporting our findings identified aminoglycosides and co-trimoxazole as potentially effective antibiotics against staphylococci clinical isolates (21-24). Our results have shown a very high rate of overall resistance and a diminishing choice of effective antibiotics, particularly for Gram-negative bacteria. This would indicate an urgent need to improve infection control and prevention of catheter-related bloodstream infections. Consistent with our findings, it seems that carbapenem resistance is increasing in the country (25-27).

In summary our study discovered a significantly high rate of intravascular catheter-associated infections, as well as an alarmingly high rate of multidrug-resistant Gram-negative organisms. This finding necessitates the implementation of a more effective infection control policy immediately. Additionally, our observations provide critical data for making more targeted empirical antibiotic selections based on the local antibiotic susceptibility pattern. Finally, it is recommended that additional studies using larger sample size and a multicentre approach be conducted to determine the factors affecting the incidence, aetiology, and trends of antibiotic resistance in catheter-related bloodstream infections.

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