Risk Factors and Clinical Characteristics of Catheter Line-associated Bloodstream Infection in MIMIC IV Database

Fang Li
  Jinan University First Affiliated Hospital

Fan Lu
  Jinan University First Affiliated Hospital

Luming Zhang
  Jinan University First Affiliated Hospital

Longzhu Li
  Jinan University First Affiliated Hospital

Mingyao Xing
  The Second Affiliated Hospital of Bengbu Medical College

Tao Shen
  The Second Affiliated Hospital of Bengbu Medical College

Haiyan Yin
  Jinan University First Affiliated Hospital

Jun Lyu (✉ lyujun2020@jnu.edu.cn)
  The First Affiliated Hospital of Jinan University

Abstract

Background: Central line-associated bloodstream infection (CLABSI) is a common hospital infection. The increasing use of peripherally inserted central catheters and fully implanted venous ports, data on the epidemiological and clinical characteristics of CLABSI in the overall central venous catheter (CVC) population remain limited. The Medical Information Mart for Intensive Care (MIMIC IV) database is a free, open, and public resource research database. The purpose of this study was to describe the risk factors and clinical characteristics of CLABSI in MIMIC IV.

Methods: A total of 31,116 patients were included in this study. General information, CVC-related information, comorbidity information, microbiological information, and antibiotic use information were extracted to describe and analyze the clinical characteristics of patients with CLABSI.

Results: According to the occurrence of CLABSI, 31,116 patients were divided into the NO CLABSI group (n=30,395) and CLABSI group (n=721). The total indwelling duration of CVC was 439,239.6 days, The incidence of CLABSI is 2.32% and 1.64/1000 catheter days. The risk factors for CLABSI were the number of CVC type, duration of CVC, number of antibiotic type, duration of antibiotics, and femoral vein and internal jugular vein intubation. The in-hospital mortality of the CLABSI group was higher than that of the NO CLABSI group, but no statistical significance was observed (P>0.05). Gram-positive (G+) cocci and Gram-negative (G-) bacilli accounted for 80% and 16.93% of positive bacteria in catheter culture. G+ cocci and G- bacilli accounted for 59.45% and 25.62% of positive bacteria in blood culture. Drugs with the highest resistance rates in catheter culture included penicillin G benzathine, oxacillin, and erythromycin. The most commonly used antibiotics for the treatment of CLABSI included vancomycin, cefepime, piperacillin tazobactam, and cefazolin.

Conclusions: This study investigated independent risk factors for CLABSI and their association with in-hospital mortality and described the etiological characteristics, drug sensitivity, and the distribution of antibiotics used for treatment.

1. Introduction

A central venous catheter (CVC) is a catheter inserted through the great vessels and peripheral vessels with the tip located in the superior or inferior vena cava. Some of the available CVCs include double-lumen catheters, triple-lumen catheters, dialysis catheters, peripherally inserted central catheters (PICCs), and totally implantable venous infusion port (PORT). CVCs are one of the indispensable tools in modern medical practice. However, the use of CVCs may lead to catheter-related infection, which has an important impact on the prognosis of patients.

The mean incidence of central line-associated bloodstream infection (CLABSI) in acute care hospital units in the United States ranges from 0 to 2.9/1000 catheter days [1]. Studies have shown that compared with conventional CVCs, PICCs have no significant difference in CLABSI rate in ICU patients [2], but the rate is significantly reduced in onco-hematologic patients. The incidence of CLABSI in cancer patients with PORT is

much lower than that of patients with PICC [3]. Between 2008 and 2014, the incidence of CLABSI decreased by 50% [4], but 30,000 new cases of CLABSI occur in the United States annually [5].

Previous studies on CLABSI in intensive care units focused on conventional double-lumen catheters, triple-lumen catheters, and dialysis catheters. With the increasing application of PICCs and PORT, the overall situation of CLABSI may change. In this study, we analyzed data from the Medical Information Mart for Intensive Care (MIMIC) IV database to understand the epidemiology and microbiological distribution of CLABSI in patients with indwelling CVC during hospitalization and to explore potential association hypotheses.

2. Materials And Methods

2.1 Data sources

The MIMIC IV database contains medical records of patients admitted to Beth Israel Deaconess Medical Center (BIDMC) between 2008 and 2019. The database contains detailed information about in-hospital patients, including International Classification of Diseases, Revision 9 (ICD-9); Clinical Revision (ICD-9-CM) codes; laboratory data; vital signs; drug administration; and mortality data [6]. The database also provides disease severity scores on the first day of each ICU admission[7].

2.2 Variable selection

In this study, we queried the derived table INVASIVA_LINE of the database system and selected all patients with indwelling catheter (n = 44,979). The exclusion criteria were as follows: 1. length of hospital stay (Los hospital) < 24 h (n = 856), 2. patients younger than 18 years old (n = 0), and 3. patients with other tubes inserted (n = 13,007), as shown in Fig. 1. CVC information was extracted on the basis of patient ID (intubation location, duration of indwelling catheter, number of tubes inserted), demographic characteristics (gender, age, weight, race, and marital status), and six different disease severity scores on the first day of admission. The disease severity scores included Oxford Acute Disease Severity Score, Sequential Organ Failure Assessment (SOFA), Simplified Acute Physiology Score, Simplified Acute Physiology Score II, Acute Physiology Score III (APSIII), and Logical Organ Dysfunction Score. The database also queried comorbidities and hospitalizations (Los ICU, Los hospital, and discharge outcome) for each patient. The type and course of antibiotics and microbiological and drug sensitivity results of blood culture and catheter culture were determined during hospitalization.

The outcome of the event was the definitive diagnosis of CLABSI and in-hospital mortality. Patients with CLABSI were identified using ICD-9 diagnostic codes 999.31 and 999.32.

The project was approved by the institutional review boards of Massachusetts Institute of Technology (MIT) and BIDMC, which was granted a waiver of informed consent.

2.3 Data processing

The missing values in this study were less than 20%. The missing data were filled by multiple inference method. Ten estimated datasets were obtained using the "mice" package of R software. The classification

variables were described as frequency and percentage values, and the differences between queues were determined by chi-square or Fisher exact test. Continuous variables were tested by Shapiro–Wilk test to verify whether they conform to normal distribution. Continuous variables were described as values in the range of mean and standard deviation values or median and quartile values, depending on whether they conform to a normal distribution.

Logistic regression was used to determine the independent risk factors for CLABSI in CVC patients. Positive LN stepwise regression was used to screen variables. The identified independent prognostic factors were analyzed again using logistic regression models, and the results were expressed as odds ratios (ORs) and 95% confidence intervals (CIs). The outcome of in-hospital mortality and Los hospital were analyzed by proportional hazard Cox regression analysis, and the original hazard ratio (HR) of patients with different CVC types was determined by CLABSI correlation variables. The probability of α error less than 5% ($P < 0.05$) was considered statistically significant. The calculated confidence interval was 95%.

R (4.0.3) was used for statistical analysis, and $P < 0.05$ was considered statistically significant.

3. Results

3.1 Baseline data

According to the occurrence of CLABSI, 31,116 patients were divided into the NO CLABSI group (n=30,395) and CLABSI group (n=721). The total catheter duration was 439,239.6 days, with an incidence of 2.32% and 1.64/1000 catheter days. Patients in the CLABSI group were younger, with a median age of 62 years, lower urine output on the first day of admission, higher SOFA, and APS III scores, and higher infection rates in all races except whites. Moreover, they had higher congestive heart failure, peptic ulcer disease, mild liver disease, diabetes with complexcomplications, renal failure, and malignant cancer; use of more number of antibiotic types; longer duration of antibiotic use; more use of RRT; and longer duration of CVC (P<0.05). The use of indwelling CVC in the femoral vein was significantly different between the two groups (P<0.001). The proportion of CLABSI group increased with the number of CVC, and the difference between groups was statistically significant (P<0.001). The CLABSI group had higher in-hospital mortality, but the Los ICU, Los hospital, and in-hospital mortality were not significantly different between the two groups (P<0.05).

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Table 1
Patient characteristics

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	NO CLABSIs(n = 30395)	CLABSIs(n = 721)	P value
Demographic Characteristics			
Age	66.00[56.00,76.00]	62.00[49.00,72.00]	< 0.001
Gender = male/female(%)	13407/16988(44.1/55.9)	338/383(46.9/53.1)	0.149
Weight	80.00[67.30,95.10]	78.50[66.10,95.00]	0.271
Urine output	1470.00[850.00,2295.00]	1255.00[517.00,2220.00]	< 0.001
Marital status (%)			0.085
Married	13780(45.3)	310(43.0)	
Unmarried	14233(46.8)	365(50.6)	
Other	2382(7.8)	46(6.4)	
Ethnicity (%)			< 0.001
White	20214(66.5)	451(62.6)	
Black	3302(10.9)	105(14.6)	
Asian/Hispanic/Latino	2016(6.6)	67(9.3)	
Unknow	4863(16.0)	98(13.6)	
Severity of Illness			
SOFA	6.00[4.00,9.00]	7.00[5.00,10.00]	< 0.001
Apsiii	51.00[37.00,71.00]	63.00[47.00,81.00]	< 0.001
OASIS	32.00[26.00,39.00]	33.00[26.00,39.00]	0.626
SAPS II	36.00[28.00,46.00]	35.00[28.00,46.00]	0.743
LODS	5.00[3.00,7.00]	5.00[3.00,7.00]	0.703
SIRS	3.00[2.00,3.00]	3.00[2.00,3.00]	0.333
Charlson comorbidity index	6.00[4.00,8.00]	6.00[4.00,8.00]	0.589
Comorbidities			
Myocardial infarct = NO/YES(%)	24582/5813(80.9/19.1)	605/116(83.9/16.1)	0.045

	NO CLABSIs(n = 30395)	CLABSIs(n = 721)	P value
Congestive heart failure = NO/YES (%)	20641/9754(67.9/32.1)	429/292(59.5/40.5)	< 0.001
Peripheral vascular disease = NO/YES (%)	26423/3972(86.9/13.1)	638/83(88.5/11.5)	0.242
Cerebrovascular disease = NO/YES (%)	26052/4343(85.7/14.3)	625/96(86.7/13.3)	0.493
Dementia = NO/YES (%)	29397/998(96.7/3.3)	709/12(98.3/1.7)	0.02
Chronic pulmonary disease = NO/YES (%)	22083/8312(72.7/27.3)	529/192(73.4/26.6)	0.7
Rheumatic disease = NO/YES (%)	29187/1208(96.0/4.0)	692/29(96.0/4.0)	1
Peptic ulcer disease = NO/YES (%)	29276/1119(96.3/3.7)	679/42(94.2/5.8)	0.004
Mild liver disease = NO/YES (%)	25657/4738(84.4/15.6)	574/147(79.6/20.4)	0.001
Diabetes without cc = NO/YES (%)	22528/7867(74.1/25.9)	536/185(74.3/25.7)	0.926
Diabetes with cc = NO/YES (%)	26592/3803(87.5/12.5)	610/111(84.6/15.4)	0.024
Paraplegia = NO/YES (%)	28906/1489(95.1/4.9)	689/32(95.6/4.4)	0.632
Renal disease = NO/YES (%)	22463/7932(73.9/26.1)	453/268(62.8/37.2)	< 0.001
Malignant cancer = NO/YES (%)	25885/4510(85.2/14.8)	592/129(82.1/17.9)	0.026
Severe liver disease = NO/YES (%)	28005/2390(92.1/7.9)	654/67(90.7/9.3)	0.181
Metastatic solid tumor = NO/YES (%)	28325/2070(93.2/6.8)	689/32(95.6/4.4)	0.015
Aids = NO/YES (%)	30125/270(99.1/0.9)	714/7(99.0/1.0)	0.974
Sepsis = NO/YES (%)	12747/17648(41.9/58.1)	295/426(40.9/59.1)	0.609
Interventions			
Number of antibiotic species	2.00[1.00,4.00]	3.00[2.00,5.00]	< 0.001
Duration of antibiotic (h)	128.00[31.00,298.00]	227.00[75.00,507.00]	< 0.001
Rrt = NO/YES (%)	28129/2266(92.5/7.5)	598/123(82.9/17.1)	< 0.001
Vasopressor = NO/YES (%)	27545/2850(90.6/9.4)	662/59(91.8/8.2)	0.306
InvasiveVent = NO/YES (%)	15658/14737(51.5/48.5)	350/371(48.5/51.5)	0.124
Blood culture = NO/YES (%)	14124/16271(46.5/53.5)	353/368(49.0/51.0)	0.198
Cathete or line culture = NO/YES (%)	27356/3039(90.0/10.0)	647/74(89.7/10.3)	0.864

	NO CLABSIs(n = 30395)	CLABSIs(n = 721)	P value
Location of CVC			
Internal jugular vein = NO/YES (%)	22306/8089(73.4/26.6)	513/208(71.1/28.9)	0.180
Subclavian = NO/YES (%)	28635/1760(94.2/5.8)	686/35(95.1/4.9)	0.287
Femoral = NO/YES (%)	26645/3750(87.7/12.3)	574/147(79.6/20.4)	< 0.001
Upper limb = NO/YES (%)	15998/14397(52.6/47.4)	395/326(54.9/45.1)	0.253
Other = NO/YES (%)	29963/432(98.6/1.4)	716/5(99.3/0.7)	0.139
Type of CVC			
Dialysis catheter = NO/YES (%)	26926/3469(88.6/11.4)	490/231(68.0/32.0)	< 0.001
Hickman catheter = NO/YES (%)	30069/326(98.9/1.1)	671/50(93.1/6.9)	< 0.001
Multi Lumen catheter = NO/YES (%)	11035/19360(36.3/63.7)	327/394(45.4/54.6)	< 0.001
PICC = NO/YES (%)	18728/11667(61.6/38.4)	352/369(48.8/51.2)	< 0.001
PORT = NO/YES (%)	28933/1462(95.2/4.8)	682/39(94.6/5.4)	0.513
Triple introducer = NO/YES (%)	30341/54(99.8/0.2)	721/0(100.0/0.0)	0.496
Indicators of CVC			
Number of CVC species(%)			< 0.001
1	25026(82.3)	421(58.4)	
2	4826(15.9)	246(34.1)	
3	512(1.7)	46(6.4)	
4	31(0.1)	8(1.1)	
Duration of CVC (h)	59.27[28.27,133.43]	96.48[41.88,250.48]	< 0.001
Outcome			
Los icu (d)	2.75[1.46,5.29]	2.75[1.46,5.00]	0.792
Los hospital (d)	9.06[5.61,16.64]	8.87[5.63,15.64]	0.505
In hostipal mortality = NO/YES(%)	26213/4182(86.2/13.8)	616/105(85.4/14.6)	0.572

	NO CLABSIs(n = 30395)	CLABSIs(n = 721)	*P value*

Peripherally inserted central venous catheters :PICC,Totally implantable venous infusion port:PORT,Central venous catheter:CVC,Central line-associated bloodstream infections:CLABSI,Length of stay:Los, Oxford Acute Disease Severity Score :OASIS, Sequential Organ Failure Assessment :SOFA, Simplified Acute Physiology Score :SAPS, Simplified Acute Physiology Score II:SAPSII, Acute physiology Score III:APSIII, Logical Organ Dysfunction Score:LODS,Complex complications:cc

3.2 Risk factors for CLABSI

Table 2 summarizes the risk factors of CLABSI. Univariate analysis showed that the number of CVC types increased and the OR value increased; duration of CVC (OR: 1.0011, 95% CI: 1.0010−1.0013), number of antibiotic types (OR: 1.1800, 95% CI: 1.1409−1.2198), duration of antibiotics (OR: 1.0009, 95% CI: 1.0008−1.0010), femoral vein intubation (OR: 3.1375, 95% CI: 2.5381−3.8445) and internal jugular vein intubation (OR: : 11.3639, ,95% CI: ⬜1.1107-−1.6605). After multivariate correction, internal jugular vein intubation (OR: 0.9266, 95% CI: 0.7788-−1.0978), other variables remain the rick factors.

Table 2
The univariate and multivariate logistic regression:risk factors for CLABSI.

CLABSIs	model 1				model 2			
	OR	2.50%	97.50%	*P value*	OR	2.50%	97.50%	*P value*
Number of cvc species								
1	Reference				Reference			
2	3.0301	2.5785	3.5534	< 0.001	2.4259	2.0375	2.8829	< 0.001
3	5.3407	3.8442	7.2526	< 0.001	3.6155	2.5476	5.0297	< 0.001
4	15.3404	6.5339	31.9813	< 0.001	10.7902	4.5252	22.9441	< 0.001
Duration of CVC	1.0011	1.0010	1.0013	< 0.001	1.0008	1.0006	1.0010	< 0.001
Number of antibiotics species	1.1800	1.1409	1.2198	< 0.001	1.1171	1.0767	1.1585	< 0.001
The duration of antibiotic	1.0009	1.0008	1.0010	< 0.001	1.0007	1.0005	1.0008	< 0.001
Subclavian vein								
NO	Reference				Reference			
YES	0.9710	0.8188	1.1465	0.7320	1.1057	0.8950	1.3548	0.3417
Jugularis interna vena								
NO	Reference				Reference			
YES	1.3639	1.1107	1.6605	0.0025	0.9266	0.7788	1.0978	0.3836
Femoral vein								
NO	Reference				Reference			
YES	3.1375	2.5381	3.8445	< 0.001	2.6865	2.1610	3.3119	< 0.001
Upper limb blood vessel								
NO	Reference				Reference			
YES	0.9108	0.7848	1.0562	0.2170	0.9588	0.8231	1.1162	0.5882

model 1	model 2
model 1: univariate analysis	
model 2: multivariate analysis(apsiii,age,gender,congestive heart failure,malignant cancer,renal disease, metastatic solid tumor)	
Peripherally inserted central venous catheters :PICC,Totally implantable venous infusion port:PORT,Central venous catheter:CVC,Central line-associated bloodstream infections:CLABSI	

3.3 CLABSI and in-hospital mortality

Univariate and multivariate COX regression analysis were used in the total CVC population and subpopulations using different CVC types including dialysis catheter, Hickman catheter, multi-lumen catheter, PICC, and PORT. The results showed that CLABSI, number of CVC types, duration of CVC, number of antibiotic type, and duration of antibiotics were not statistically correlated with mortality ($P < 0.05$). The duration of antibiotic use was a protective factor only in the Hickman catheter group after multifactor correction (HR: 0.9988, 95% CI: 0.9978−0.9997), as shown in Table 3.

Tabel 3

The univariate and multivariate cox regression: risk factors for in-hospital mortality in patients with different type of CVC

		model 1				model 2			
		HR	5%	95%	P value	HR	5%	95%	P value
CVC	Number of CVC species	1.0130	0.9761	1.0520	0.4850	0.9995	0.947	1.055	0.9847
	Duration of CVC indwelling	1.0000	0.9990	1.0000	0.3480	1.0001	0.9999	1	0.3072
	Number of antibiotics species	0.9991	0.9837	1.0150	0.9090	0.9983	0.976	1.021	0.8838
	The duration of antibiotic use	1.0000	0.9999	1.0000	0.9550	0.9999	0.9998	1	0.5156
	CLABSIs								
	NO	1				1			
	YES	1.0890	0.8970	1.3210	0.3900	1.0904	0.8966	1.326	0.3861
Dialysis	Number of CVC species	1.0470	0.9903	1.1070	0.1060	1.0602	0.9671	1.162	0.212
	Duration of CVC indwelling	1.0000	0.9999	1.0000	0.3230	1.0001	0.9997	1.001	0.548
	Number of antibiotics species	1.0080	0.9739	1.0440	0.6460	1.0075	0.9537	1.064	0.789
	The duration of antibiotic use	1.0000	0.9998	1.0000	0.9440	0.9998	0.9994	1	0.206
	CLABSIs								
	NO	1				1			
	YES	1.3040	0.9516	1.7880	0.0986	1.2933	0.9375	1.784	0.117
Hickman	Number of CVC	1.0870	0.9599	1.2310	0.1890	1.0584	0.7535	1.4867	0.7435

	species								
	Duration of CVC indwelling	1.0000	1.0000	1.0010	0.0599	1.001	0.9999	1.002	0.0767
	Number of antibiotics species	1.0730	0.9696	1.1860	0.1740	1.1538	0.9709	1.3711	0.1042
	The duration of antibiotic use	1.0000	0.9997	1.0010	0.5930	0.9988	0.9978	0.9997	0.0116
	CLABSIs								
	NO	1				1			
	YES	0.4770	0.1491	1.5260	0.2120	0.4473	0.1336	1.498	0.192
Multi lumen	Number of CVC species	1.0010	0.9603	1.0430	0.9700	0.9805	0.9205	1.044	0.5404
	Duration of CVC indwelling	1.0000	0.9999	1.0000	0.7150	1.0002	0.9999	1	0.2743
	Number of antibiotics species	0.9931	0.9741	1.0120	0.4780	0.9947	0.9673	1.023	0.7115
	The duration of antibiotic use	1.0000	0.9999	1.0000	0.5440	0.9999	0.9997	1	0.4364
	CLABSIs								
	NO	1				1			
	YES	1.0940	0.8418	1.4230	0.5010	1.1067	0.8468	1.446	0.4579
PICC	Number of CVC species	0.9956	0.9478	1.0460	0.8620	1.0036	0.9346	1.078	0.9205
	Duration of CVC indwelling	1.0000	0.9998	1.0000	0.8900	1.0001	0.9998	1	0.5554
	Number of antibiotics species	0.9916	0.9694	1.0140	0.4690	0.997	0.9638	1.031	0.8629

The duration of antibiotic use	1.0000	0.9998	1.0000	0.5370	1	0.9997	1	0.7538
CLABSIs								
NO	1				1			
YES	1.2210	0.9456	1.5770	0.1260	1.2509	0.966	1.62	0.0894

model 1：univariate analysis.

model 2：apsiii,age,gender,congestive heart failure,malignant cancer,renal disease,metastatic solid tumor

Peripherally inserted central venous catheters :PICC,Totally implantable venous infusion port:PORT,Central venous catheter:CVC,Central line-associated bloodstream infections:CLABSI,

3.4 Microorganism distribution in catheter culture and blood culture

Multiple blood cultures and catheter cultures may be performed on the same patient,, and a total of 44,453 blood cultures and 18,874 catheter cultures were collected. The positive rate of catheter culture was 62.45%, higher than 41.00% of blood culture (P < 0.001) (Table 4). G + cocci and G- bacilli accounted for 80% and 16.93% of positive bacteria in catheter culture. The top three G + cocci were *Staphylococcus epidermidis* (54.38%), *Staphylococcus aureus* coag (42.24%), and *Enterococcus* (2.9%) (Fig. 2). The top three G- bacilli were *Pseudomonas aeruginosa* (20.3%), *Serratia* (18.6%), and *Enterobacter aerogenes* (17.34%) (Fig. 3). Fungal infection was mainly caused by yeast (Table S1). Among the positive bacteria in blood culture, G + cocci accounted for 59.45%, while G- bacilli accounted for 25.62% (Table 4). The top three G + bacteria were *Staphylococcus* (49.98%), *Enterococcus* (18.33%), and *Staphylococcus aureus* (17.40%) (Fig. 4). The top three G- bacteria were *Escherichia coli* (31.91%), *Klebsiella acidophilus* (20.36%), and *Pseudomonas aeruginosa* (8.05%) (Fig. 5). Fungal infection was dominated by *Candida albicans* (Table S2). For more detailed distribution of microorganisms, see Tables S1 and S2.

Table 4

Chi-square test:the distribution of main bacteria in blood culture and catheter culture

	Blood culture		Catheter culture			
	Number	Percentage	Number	Percentage	χ^2	P
Positive result	**18225**	**41.00%**	**11786**	**62.45%**	**2444.37**	**<0.001**
G+ coccus	10834	59.45%	9485	80.48%	1447.84	<0.001
G+ bacillus	1190	6.53%	92	0.78%	578.46	<0.001
G- bacillus	4670	25.62%	1995	16.93%	313.38	<0.001
G- coccus	55	0.30%	13	0.11%	11.61	0.001
Fungus	1183	6.49%	173	1.47%	418.62	<0.001
Other	293	1.61%	28	0.24%	126.97	<0.001
Negative result	**26228**	**59.00%**	**7088**	**37.55%**		
total	44453		18874			
Gram-positive:G+, Gram-negative:G-						

3.5 Drug sensitivity and antibiotic treatment

In catheter culture, gentamicin, levofloxacin, and erythromycin were the most commonly tested drugs, as shown in Fig. 6. Penicillin G benzathine (drug sensitivity: 14.96%), oxacillin (drug sensitivity: 25.23%), erythromycin (drug sensitivity: 27.59%), levofloxacin (drug sensitivity: 29.04%), and ampicillin (drug sensitivity: 37.65%) had the highest drug resistance, and the most sensitive drugs were linezolid (drug sensitivity: 100%), daptomycin (drug sensitivity: 100%), piperacillin (drug sensitivity: 96.77%), trimethoprim sulfamethoxazole (drug sensitivity: 95.00%), imipenem (drug sensitivity: 95.00%), and meropenem (drug sensitivity: 93.12%) as shown in Fig. 7. The most commonly tested drugs in blood cultures included gentamicin, trimethoprim sulfamethoxazole, vancomycin, meropenem, and piperacillin tazobactam as shown in Fig. 8. Drugs with the highest resistance rates were erythromycin (drug sensitivity: 39.55%), oxacillin (drug sensitivity: 43.49%), ampicillin (drug sensitivity: 45.99%), levofloxacin (drug sensitivity: 49.48%), and penicillin G benzathine (drug sensitivity: 49.75%). Drugs with the highest sensitivity rates were daptomycin (drug sensitivity: 99.73%), linezolid (drug sensitivity: 97.56%), meropenem (drug sensitivity: 91.85%), amikacin (drug sensitivity: 89.69%), rifampin (drug sensitivity: 88.52%), and imipenem (drug sensitivity: 85.98%) as shown in Fig. 9. The most commonly used antibiotics for the treatment of indwelling CVC patients were vancomycin, cefepime, piperacillin tazobactam, and cefazolin, as shown in Fig. 10. The distribution of major antibiotic treatment was compared between the CLABSI group and the NO CLABSI group, with no statistically significant difference (P < 0.05), as shown in Table S3.

4. Discussion

CVC provides effective venous access for patients in critical condition and those with renal failure and cancer. It improves the success rate of resuscitation, alleviates the pain of patients, and prolongs their survival time. The International Nosocomial Infection Control Consortium (INICC) reported CLABSI is 4.9/1000 catheter days [1, 2]. The incidence of CLABSI in China is 5–15% and 2.9–11.3/1000 catheter days [8]. One study in Argentina found a 5.4% incidence of CLABSI and an infection rate of 8.7/1000 catheter days [9]. In this study, the incidence of CLABSI was 2.32%, and the infection rate of indwelling catheters was 1.64/1000 catheter days, which was consistent with the results of CLABSI epidemiological studies in the United States.

The patients with CLABSI in this study were younger and had severer conditions. Dialysis catheter is used for patients with renal failure requiring alternative therapy. Conventional CVC is more commonly used for monitoring treatment of cardiac failure. PICC and PORT are more commonly used for patients with malignant tumors, in which the indwelling time is long. In this study, age, severity, and comorbidities were included in the multivariate analysis, and the results were consistent with the univariate results. The number of CVC type and the duration of CVC were correlated with the incidence of CLABSI. A previous study showed that reducing the number of CVC and the duration of indwelling catheter can reduce the incidence of CLABSI [10].Parameswaran et al [11] found that the rate of femoral vein, intrajugular vein, and subclavian vein catheter-related infections was 33.3%, 22.2%, and 21.3%, respectively.Lorente et al [12] analyzed 2595 patients found that the femoral vein had a higher risk of CRBSI than the internal jugular vein and the subclavar vein.This study also confirmed a higher risk of CRBSI in the femoral vein.

Once CLABSI occurs, it requires more intensive antibiotic treatment, so it is also correlated with the number of antibiotic types and the duration of antibiotic treatment. Lee JH et al. also confirmed that antibiotic use was an independent risk factor for CLABSI [13]. Huerta et al. also found a significant association between duration of antibiotic use and early mortality and relapse [14].

Many studies have shown that CLABSI can significantly increase mortality and prolong hospital stay [15]. However, this study found an increase in in-hospital mortality in the CLABSI group, which was not statistically significant compared with the NO CLABSI group. The outcome of this study was in-hospital mortality. Without out-of-hospital follow-up, there may be deviations in mortality. The improvement of CLABSI prevention concept and treatment level can greatly reduce morbidity and mortality. A Study study in South Korea reduced the average CLABSI pooling rate from 3.40 in 2006 to 2.20/1,000 catheter days in 2015 [16]. In the United States, many randomized controlled trials focused on preventing CLABSI, with a 50% decline in CLABSIs between 2008 and 2014 [17], and the mortality of CLABSIs decreased [18]. Most of the previous studies are aimed at conventional CVCs, excluding PICC and PORT. The study has confirmed that the incidence of CLABSI caused by PICC is significantly lower than that of other types of CVC[19]. The in-hospital mortality of PICC CLABSI and PORT CLABSI has not been well studied, thus affecting the overall mortality. CVC is increasingly maintained outside the hospital, and out-of-hospital CLABSI needs further study.

In this study, the positive rate of catheter culture was significantly higher than that of blood culture. The six most common microorganisms in catheter culture were *Staphylococcus epidermidis*, *Staphylococcus aureus* coag, *Pseudomonas aeruginosa*, *Serratia*, and *Enterobacter aerogenes*. G + cocci accounted for 80.48%, followed by G- bacilli and fungi. Fungi were mainly yeast. A number of studies in China showed that the most common microbe was *Acinetobacter*, followed by *Staphylococcus epidermidis* and *Candida albicans* [20]. A

study in Spain showed that G + cocci accounted for the majority, followed by G- bacilli and yeasts [21], which was consistent with our results. According to CLABSI data from the Centers for Disease Control and Prevention and the National Healthcare Safety Network, fungal infections are high in adult ICUs, and *Enterobacteriaceae* and fungi are increasing in oncology wards [22]. Due to the different prevention and treatment plans of hospitals in different regions, the distribution of pathogenic microorganisms may be different. Iatrogenic factors may greatly influence catheter microbial colonization and catheter-associated infections. Hospital managers need to strengthen environmental and human monitoring and nosocomial infection control.

The distribution of microorganisms in blood culture was not consistent with that in catheter culture. The proportion of G + cocci decreased, while those of G- bacilli and fungi increased. *Staphylococcus*, *Enterococcus*, *Staphylococcus aureus* coag, *Escherichia coli*, *Candida albicans*, and intestinal bacteria increased significantly. Enterogenic bacteria enter the blood after intestinal barrier destruction, which is an important mechanism of blood-borne infection [23]. The proportion of *Candida albicans* in fungi increased. Although yeast prevalence has geographical differences, the overall level of yeast prevalence is increasing globally [24, 25]. In addition, repeated exposure to broad-spectrum antibiotics, complex surgical procedures, glucocorticoids, and other factors increases the risk of fungal infections, especially *Candida* [26].

The three most commonly monitored antibiotics in the both cultures included gentamicin, erythromycin, vancomycin, The five antibiotics with the highest drug resistance in the both cultures included penicillin G, oxacillin, erythromycin, levofloxacin, and ampicillin. Three kinds of sensitive antibiotics were found: daptomycin, linezolid, and carbapenems (meropenem, imipenem), which are all third-line antibiotics. Other sensitive antibiotics included enzyme inhibitors (piperacillin tazobactam), sulfa (trimethoprim sulfamethoxazole), rifampin (anti-tuberculosis), and amikacin. In the NO CLABSI group and CLABSI group, the distribution of antibiotics used for treatment was consistent, and the difference was not statistically significant. The overall distribution showed that the most commonly used antibiotics were vancomycin, cefepime, piperacillin tazobactam, and cefazolin. The sensitivity of blood culture was 62−82%, and that of catheter culture was 51−91%, with vancomycin and cefazolin having the highest and lowest sensitivities. Studies have shown that on the basis of etiological predictions, early source control, when initiated with antimicrobial therapy, improves prognosis [27]. Antibiotics are often used empirically at the beginning, advocating broad spectrum and high efficiency, and replaced with narrow-spectrum and high-sensitivity drugs according to etiology and drug sensitivity results. To prevent the development of resistance, antibiotic management needs to be followed [28]. At the same time, economic factors should be taken into account. This study showed that the use of antibiotics basically conformed to the results of drug sensitivity. Currently, research on the application of antibiotics for the treatment of CLABSI is insufficient.

5. Limitations

This was a single-center retrospective study. The location of catheter implantation was not recorded in some patients. The diagnosis time of CLABSI was unclear. We could not determine which catheter was the cause of CLABSI when multiple indwelling CVCs were used. All of the above factors can lead to selection bias and experimental errors.

6. Conclusions

In this study, the risk factors of CLABSI were confirmed by analyzing the data of CVC patients in the MIMIC IV database from 2008 to 2019. The in-hospital mortality of the CLABSI group was higher than that of the NO CLABSI group, but no statistical significance was observed. The etiological distribution of catheter culture and blood culture was analyzed, and the distribution of antibiotics for clinical treatment was further analyzed on the basis of drug sensitivity results.

Declarations

Declaration:

The manuscript, or part of it, neither has been published (except in form of abstract or thesis) nor is currently under consideration for publication by any other journal. All authors have read and approved this version of the article, and due care has been taken to ensure the integrity of the work. There are no any ethical/legal conflicts involved in the article.

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Figures
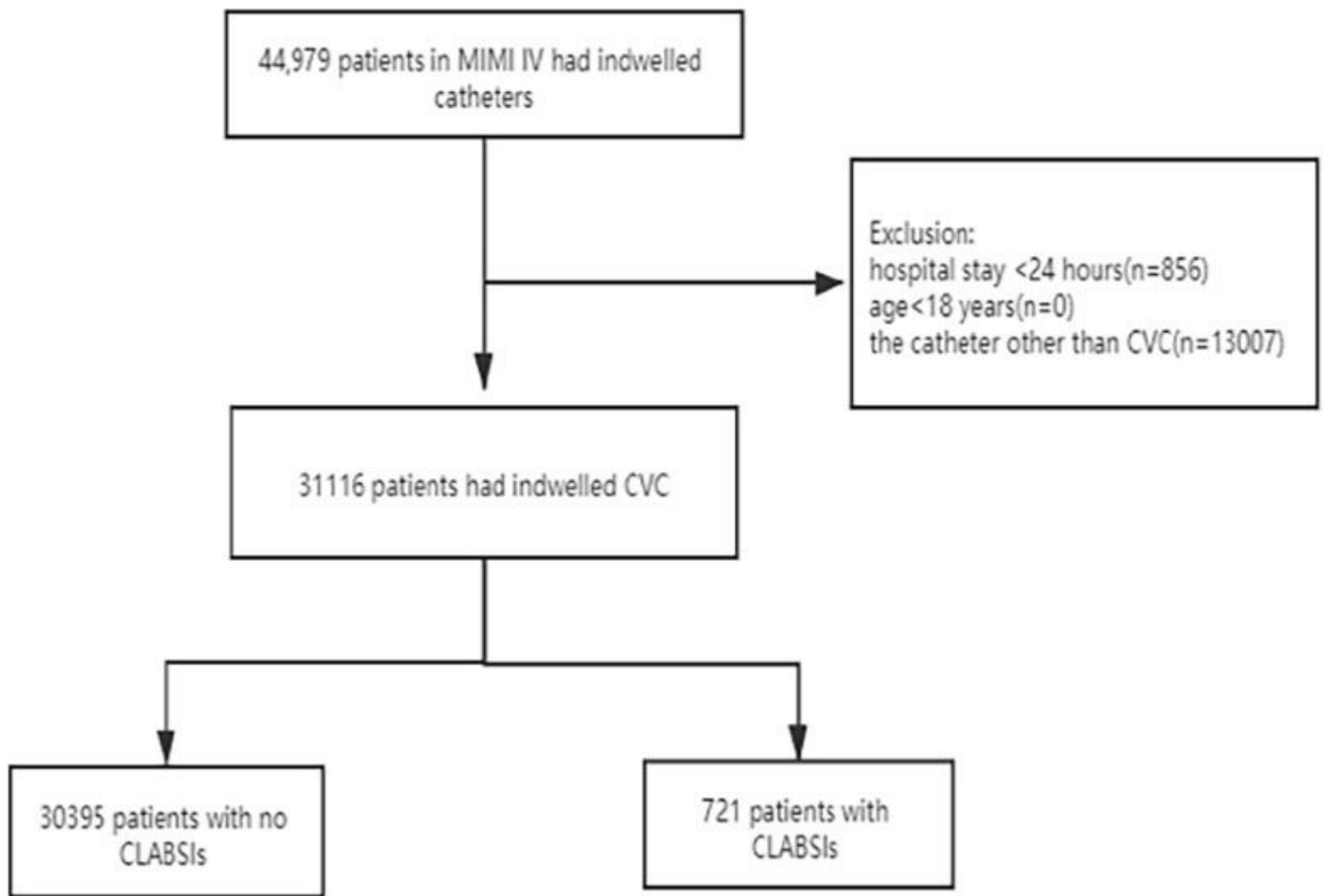
Figure 1

Flowchart of variables included in the study
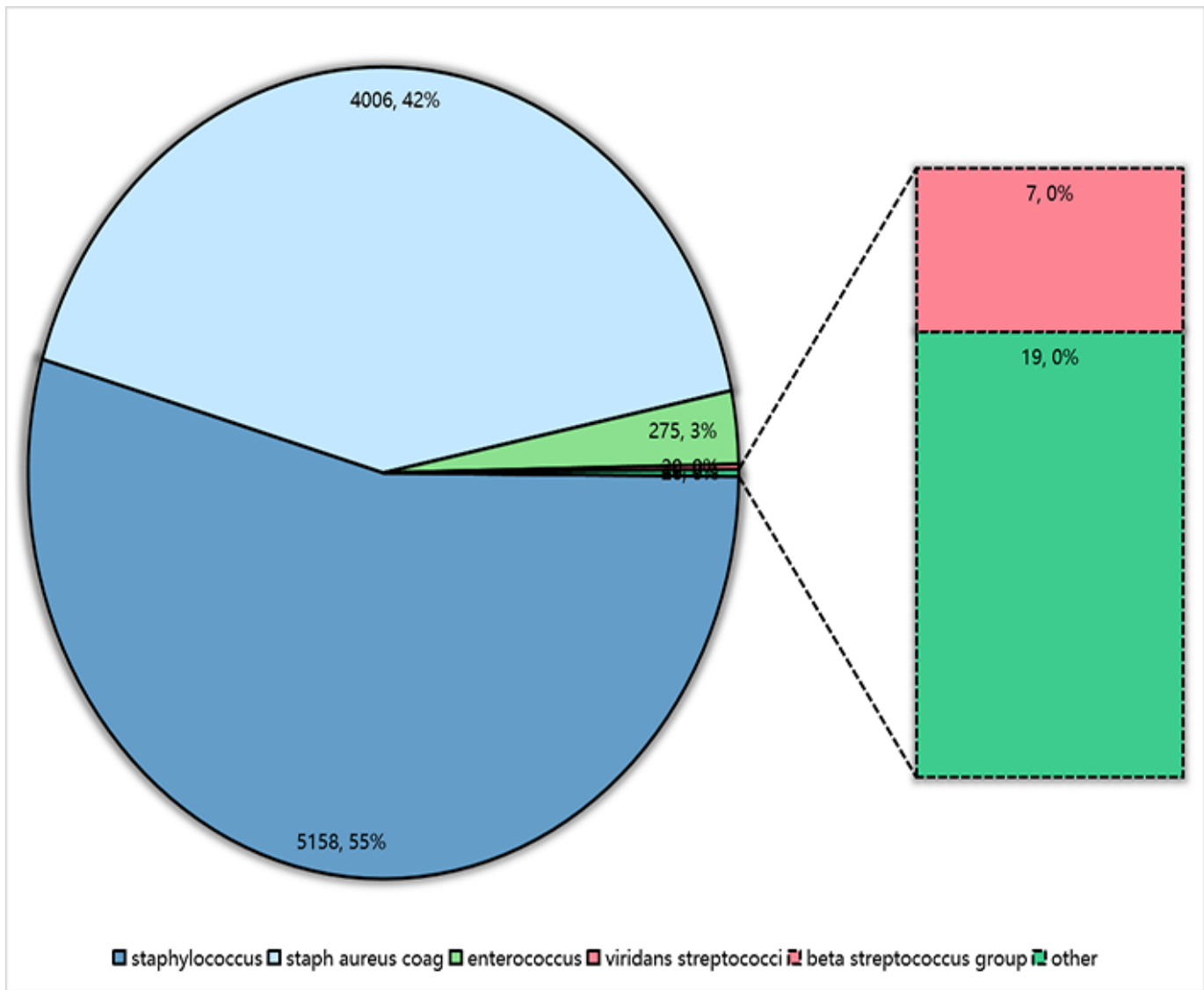
Figure 2

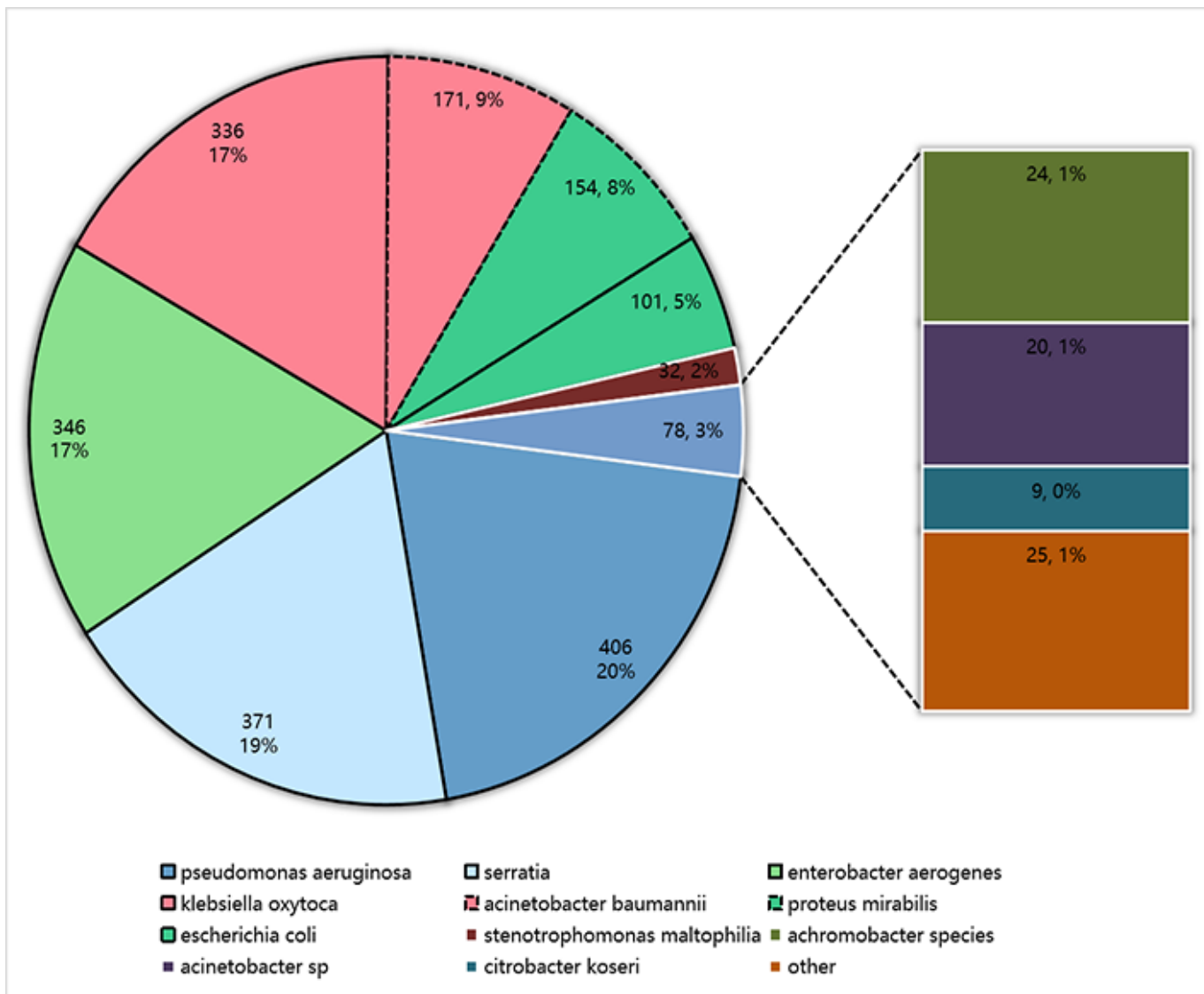Pie chart of positive cocci in catheter culture

Figure 3

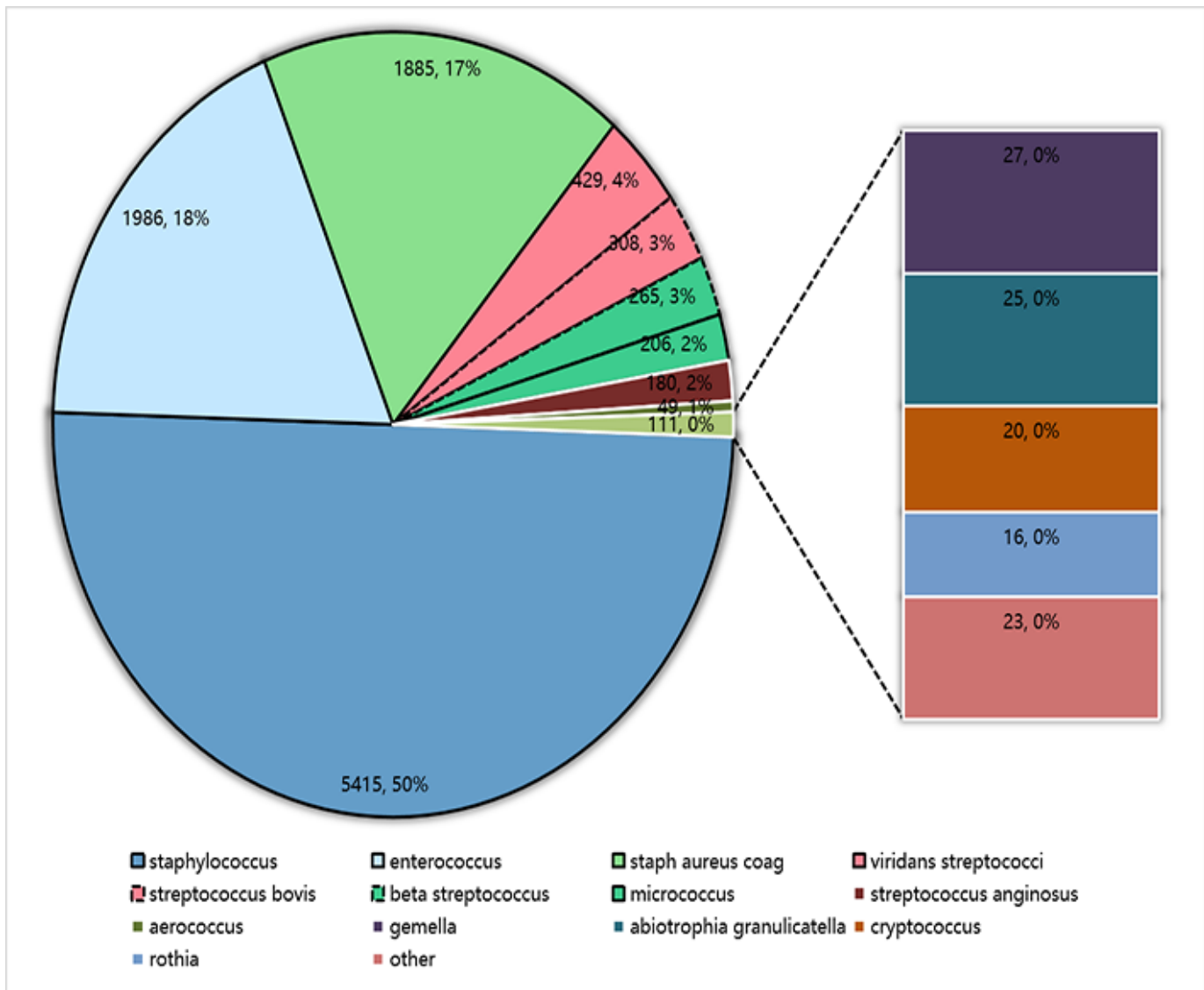Pie chart of negative bacilli in catheter culture

Figure 4

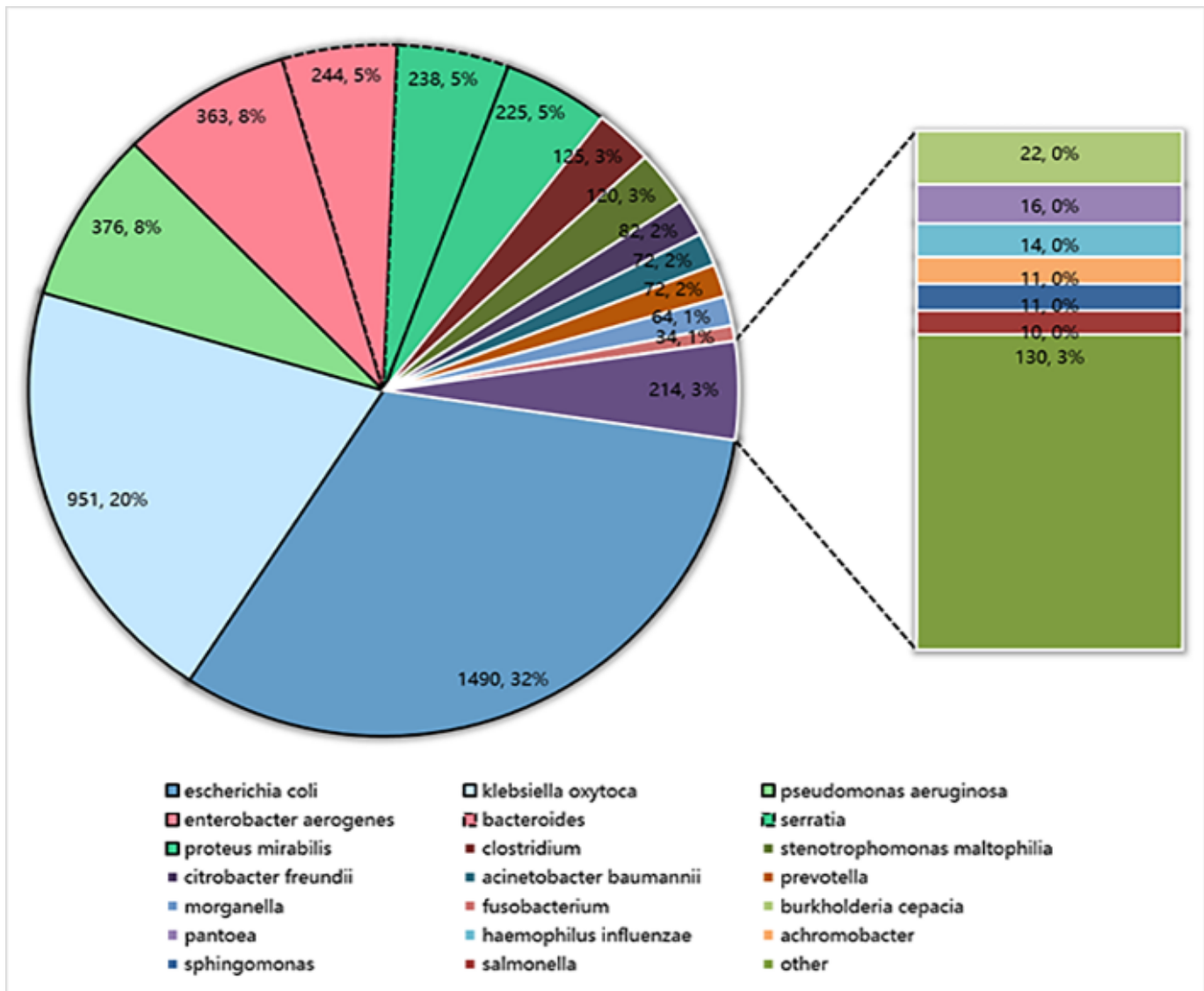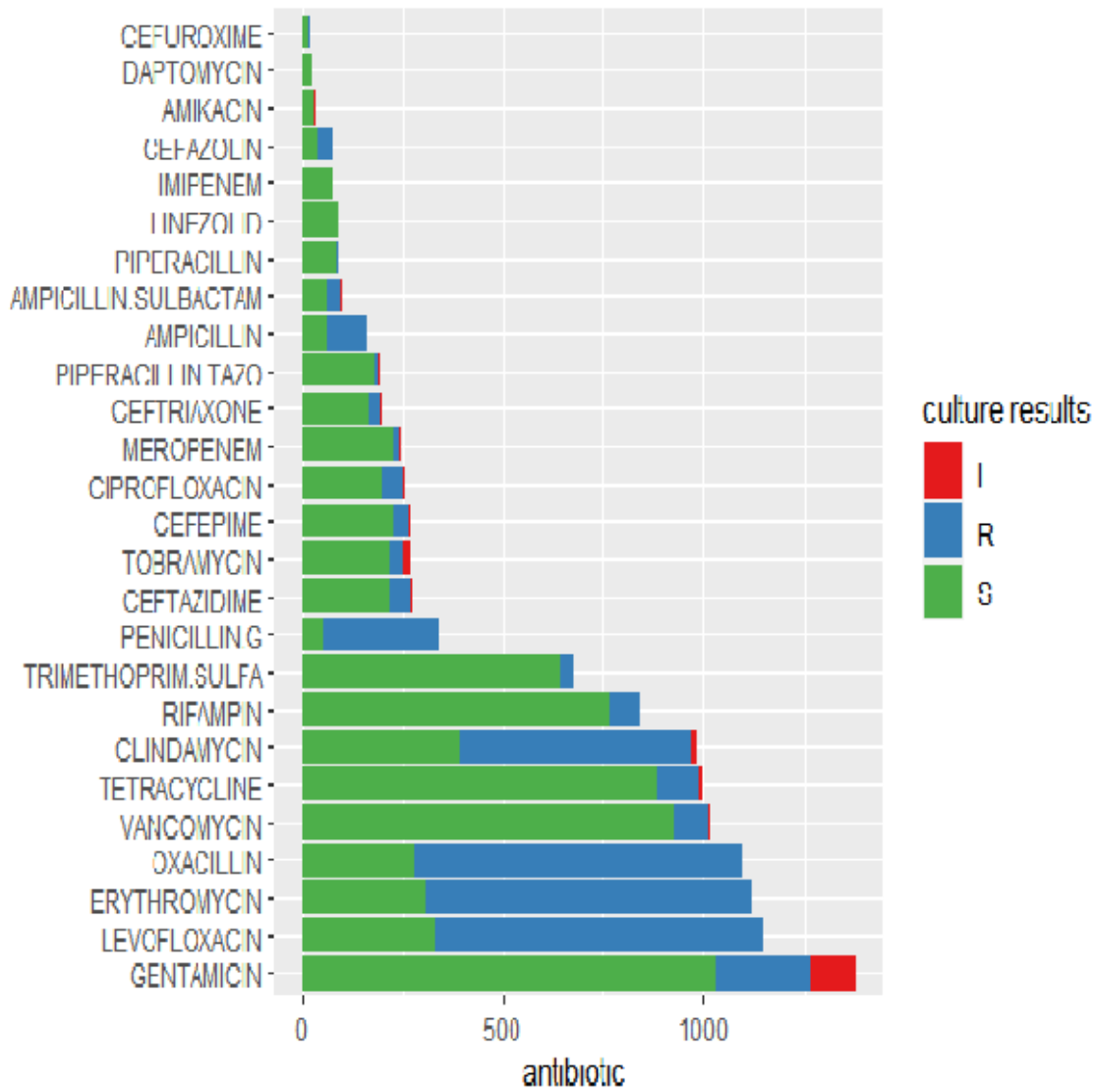Pie chart of positive cocci in blood culture
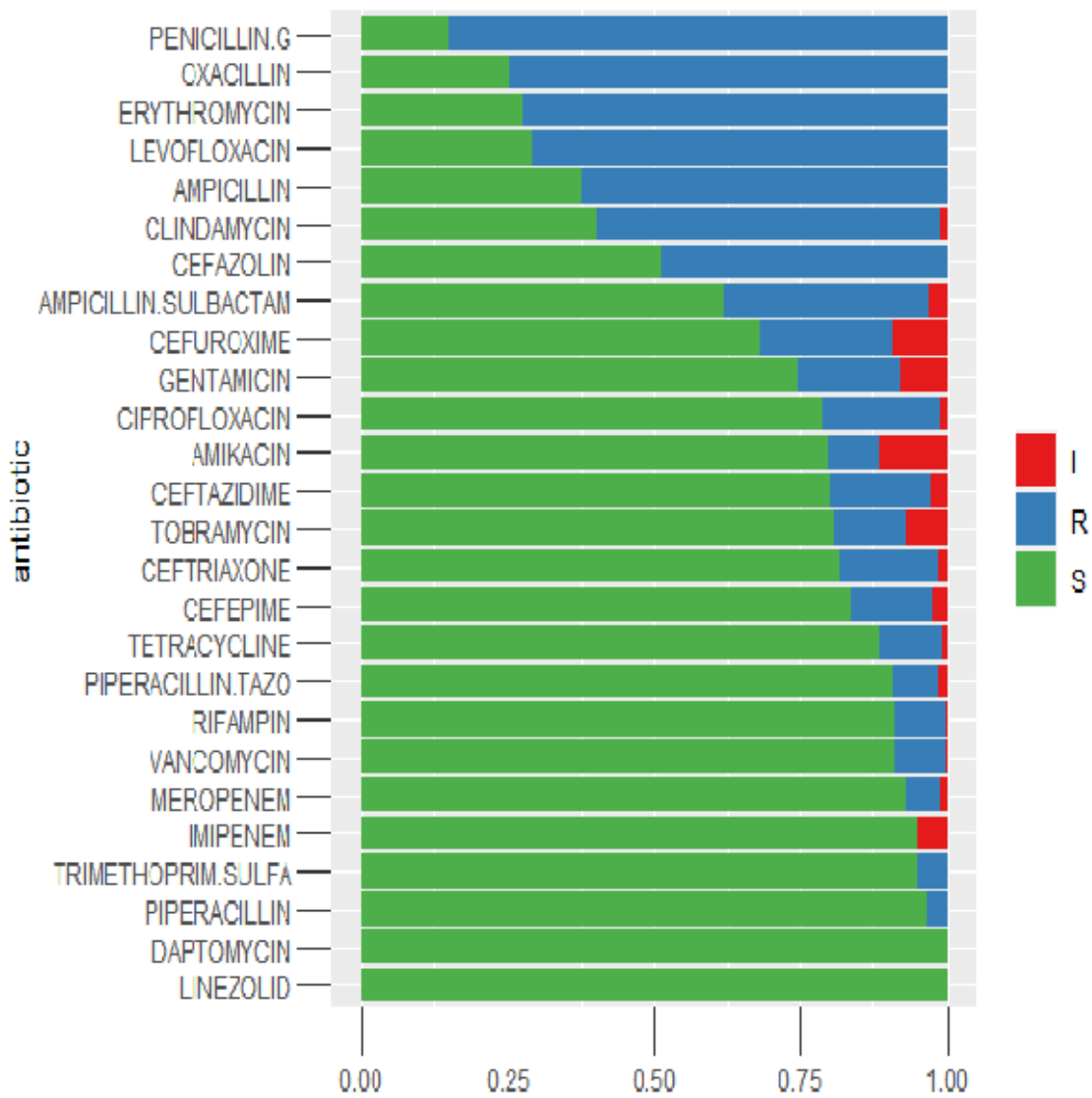
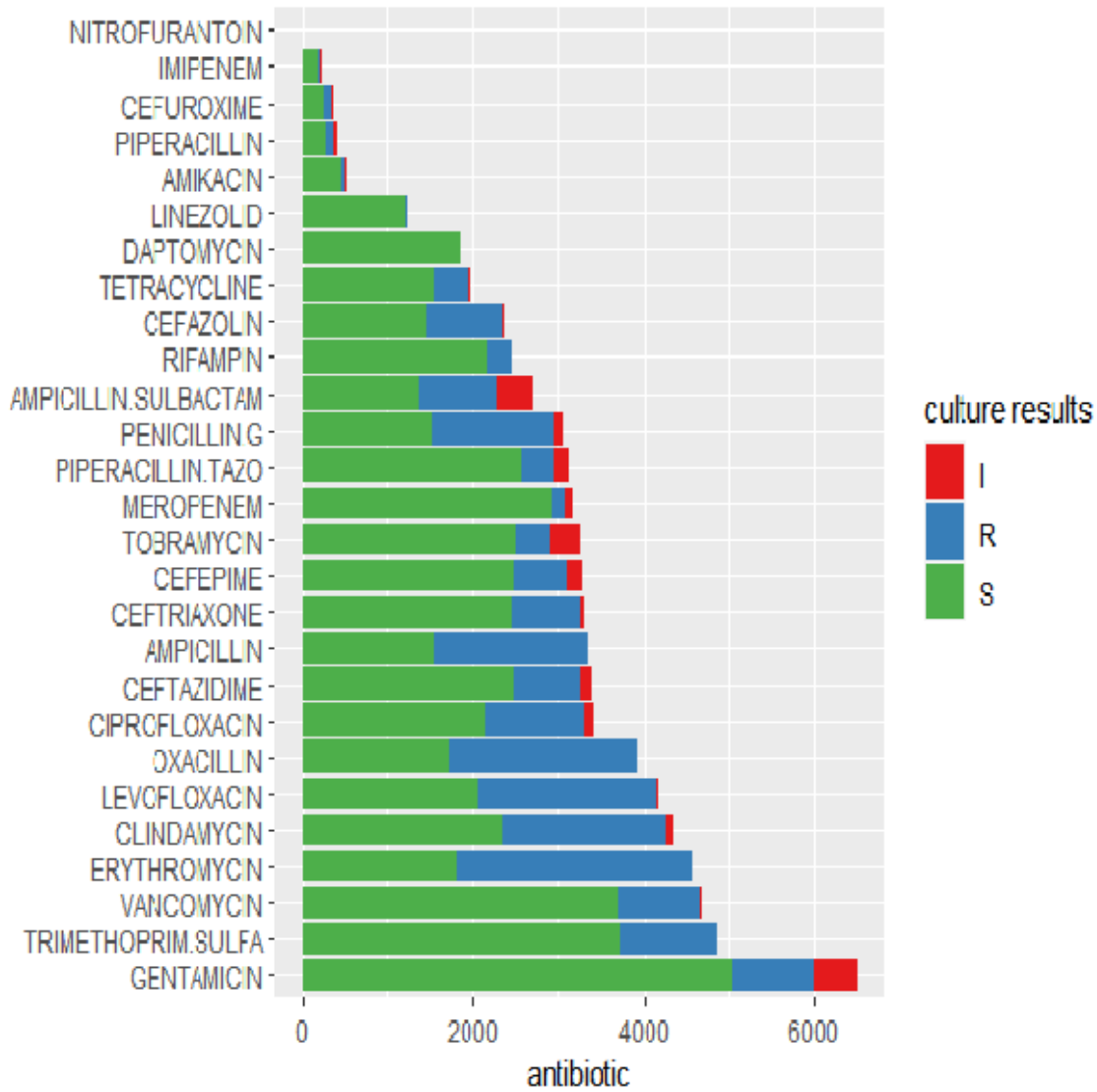**Figure 5**

Pie chart of negative bacilli in blood culture

Figure 6

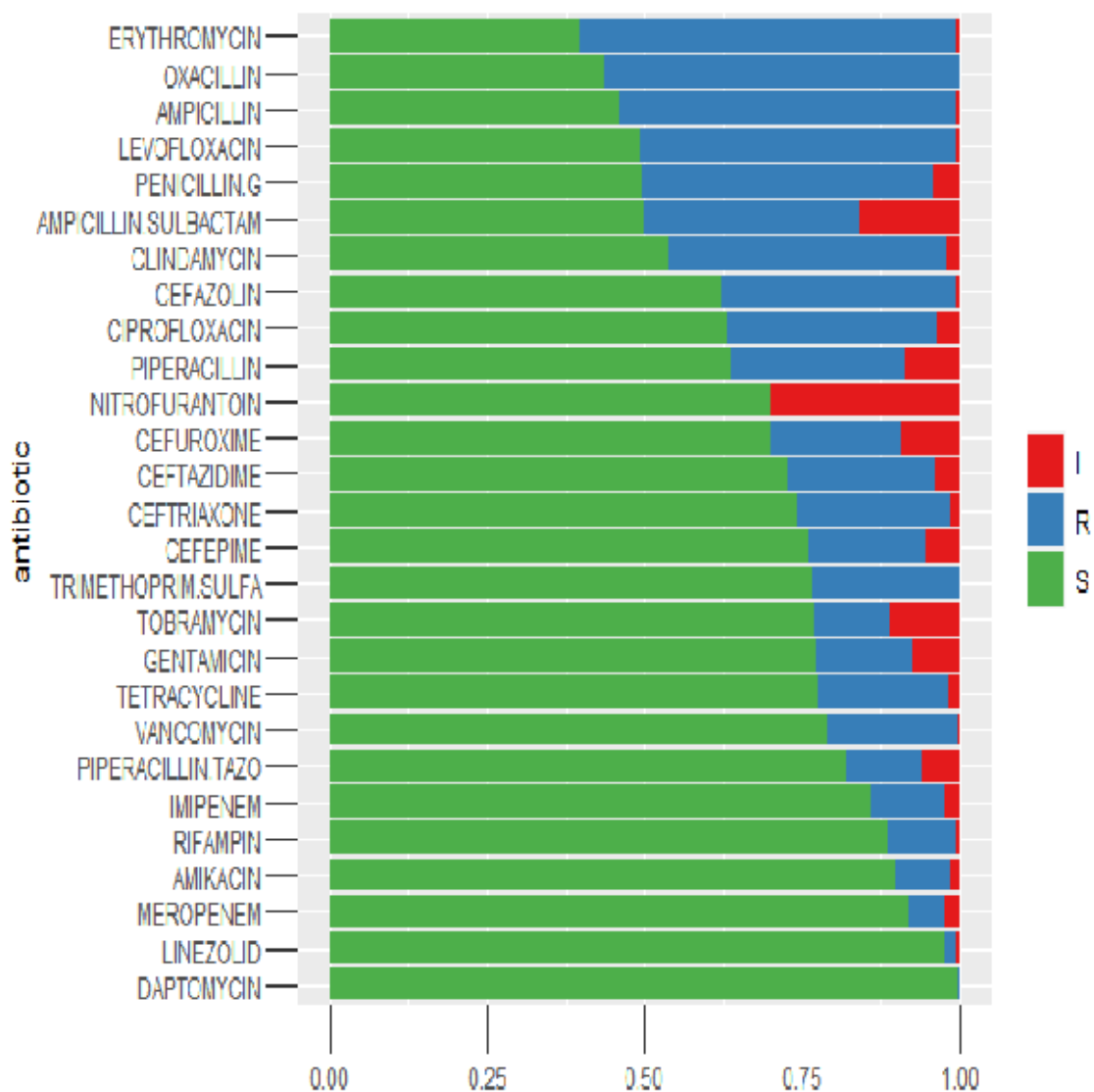Accumulation bar chart of antibiotic susceptibility distribution in catheter culture

Figure 7

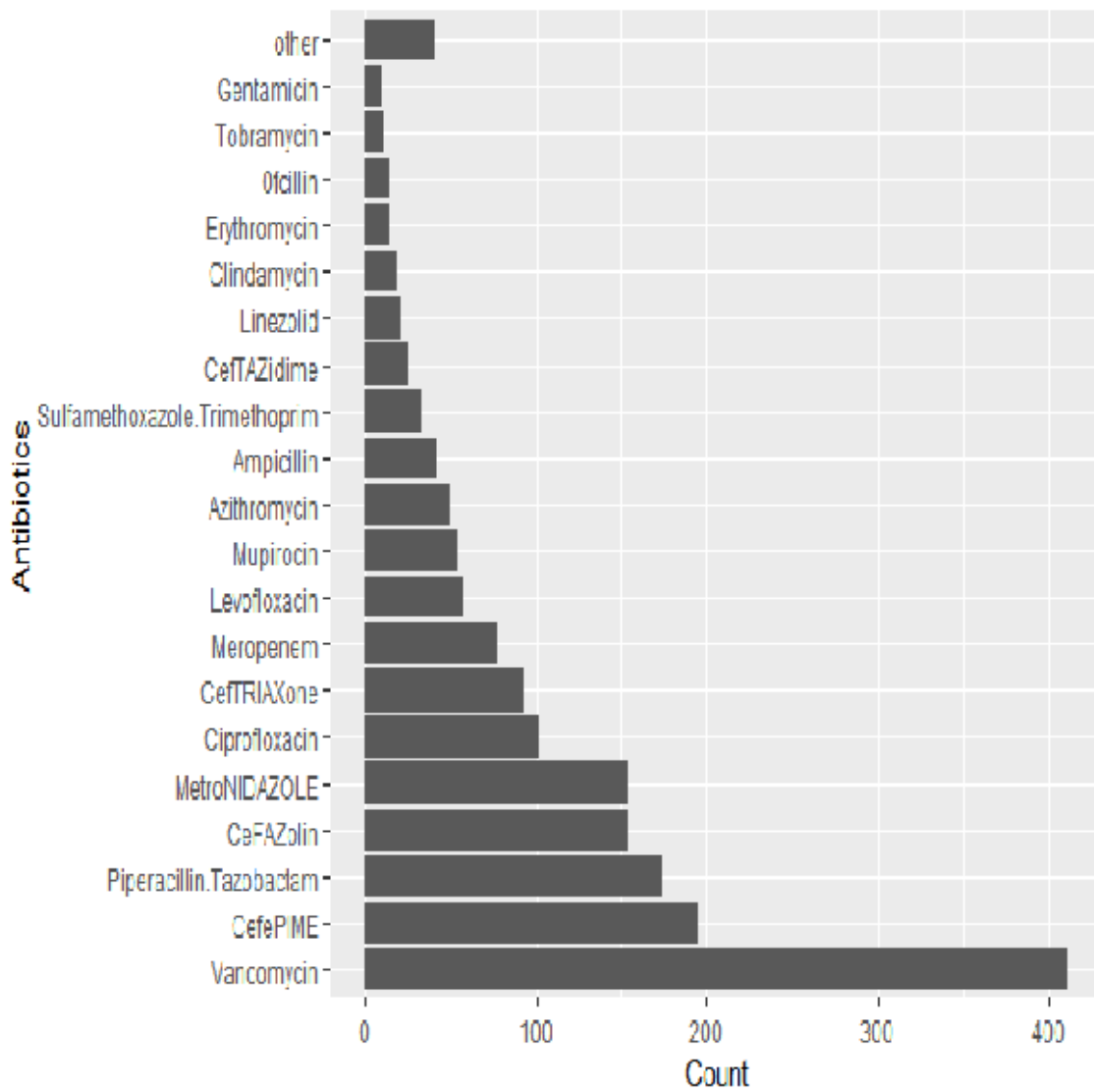Percentage of antibiotic susceptibility distribution in catheter culture

Figure 8

Accumulation bar chart of antibiotic susceptibility distribution in blood culture

Figure 9

Percentage of antibiotic susceptibility distribution in blood culture

Figure 10

Histogram of the distribution of therapeutic antibiotics

Supplementary Files

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