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ABOUT COVER

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ORIGINAL ARTICLE

Retrospective Cohort Study

Multidrug-resistant organisms in intensive care units and logistic analysis of risk factors

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Abstract

BACKGROUND

Intensive care unit (ICU) patients are critically ill and have low immunity. They will undergo various trauma medical procedures during diagnosis and treatment. The use of high-dose hormones and broad-spectrum antibiotics will increase the incidence of nosocomial infection in ICU patients. Therefore, it is necessary to explore the causes of nosocomial infection in ICU and provide basis for the prevention and control of nosocomial infection in ICU.

AIM

To explore major pathogens of nosocomial infection in ICUs, methods of detection and drug resistance trends.

METHODS

Risk factors of multidrug-resistant infection were analyzed to provide a basis for clinical rational use of antimicrobial drugs in the ICU. These findings were used to standardize rational use of antimicrobial agents. BD PhoenixTM100 automatic bacterial identification analyzer was used to for cell identification in specimens collected from the ICU between January 2016 and December 2019. Drug sensitivity tests were carried out and drug resistance trends were analyzed using the optical disc diffusion method. Odds ratios and corresponding 95%CI of independent variables were calculated using a logistic regression model. Backward elimination (trend = 0.1) was used as an inclusion criterion for multivariate analysis. All data were analyzed using SPSS version 22.0, and $P < 0.05$ was considered statistically significant.

RESULTS

We collected 2070 samples from ICU patients between January 2016 and December 2019. Sample types comprised sputum (1139 strains, 55.02%), blood (521 strains, 25.17%), and drainage fluid (117 strains, 5.65%). A total of 1051 strains of major pathogens, including *Acinetobacter baumannii*, *Escherichia coli* (*E.*

coli), *Pseudomonas aeruginosa* (*P. aeruginosa*), *Klebsiella pneumoniae* (*K. pneumoniae*) and *Staphylococcus aureus*, were detected, with a detection rate of 35.97% (378/1051). Most of these strains were resistant to antibiotics. Detection rate of *E. coli* was 21.79% (229/1051), and it was generally sensitive to many antimicrobial drugs. Detection rate of *P. aeruginosa* was 24.74% (260/1051), and showed low sensitivity to most antibiotics. Detection rate of *K. pneumoniae* was 9.42% (99/1051), which was generally resistant to multiple antimicrobial drugs and resistant forms. *K. pneumoniae* was resistant to imipenem for approximate 4 years, and showed a 19.9% (19/99) and 20.20% (20/99) rate of meropenem resistance. Logistic analysis showed that mechanical ventilation and ureteral intubation were risk factors for multidrug-resistant bacterial infections.

CONCLUSION

This study showed a high incidence of ICU infections. Mechanical ventilation and urine tube intubation were risk factors for infection with multidrug-resistant bacteria.

Key Words: Multidrug-resistant organisms; Intensive care; Antibiotics; Drug resistance

Core Tip: This study described the current situation of multi drug resistant bacteria infection in intensive care unit (ICU) patients, and analyzed the main pathogens of nosocomial infection in ICU and the risk factors of multi drug resistant bacteria infection. The results showed that mechanical ventilation and intubation were the risk factors of multidrug resistant bacterial infection. To provide effective scientific basis for improving the clinical efficacy of antibiotics and scientific strategies for the prevention and treatment of multidrug-resistant bacteria.

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INTRODUCTION

Intensive care unit (ICU) patients are critically ill and have low immunity. They undergo various traumatic medical procedures during diagnosis and treatment. The use of high-dose hormones and broad-spectrum antibiotics increase the incidence of nosocomial infection in ICU patients. Therefore, it is necessary to explore the causes of nosocomial infection in the ICU and provide a basis for the prevention and control of nosocomial infection in the ICU. This study described multidrug-resistant bacterial infection in ICU patients from January 2016 to December 2019, and analyzed the risk factors for infection by multidrug-resistant bacteria in ICU patients.

MATERIALS AND METHODS

Research methods

Bacteria were isolated from collected samples for identification and analysis following the National Operating Rules for Clinical Examination (third edition). BD PhoenixTM100 automatic bacterial identification and analysis instrument was used for cell identification. Drug sensitivity test was carried out by paper disk (provided by Oxoid) Agar diffusion method (Kirby–Bauer method). *Pseudomonas aeruginosa* (*P. aeruginosa*) ATCC27853, *Staphylococcus aureus* (*S. aureus*) ATCC25923 and *Escherichia coli* (*E. coli*) ATCC25922 were used as quality control strains.

Inclusion and exclusion criteria

Inclusion criteria were: (1) According to the definition of diagnostic criteria for nosocomial infection (2001) issued by the Ministry of Health of the People's Republic of China, and the etiological diagnosis was multidrug-resistant bacterial infection; and (2) Inpatients in the ICU.

Exclusion criteria were: (1) Diagnosis did not meet the diagnostic criteria for nosocomial infection issued by the Ministry of Health of the People's Republic of China; (2) Diagnosis of multidrug-resistant bacterial colonization without clinical infection symptoms; (3) Contaminated samples of multidrug-

resistant bacteria; and (4) Natural resistant strains.

Statistical analysis

Pathogenic bacteria detected in nosocomial samples were analyzed and sorted out by real-time monitoring system for nosocomial infection control in Xinglin. Retrospective analysis was used to investigate and collect patient records and test data. Data analysis was performed using SPSS 22.0. Logistic regression analysis was used to perform univariate and multivariate analyses for independent risk factors for multidrug-resistant infection.

RESULTS

Sample collection

A total of 2070 cases of ICU infection were recorded. The causative pathogens were mainly collected from sputum in 1139 cases (55.02%), blood in 521 (25.17%), and drainage in 117 (5.65%) (Table 1).

Distribution of pathogenic bacteria

Among the 1051 strains of main pathogens identified in ICU, 966 were Gram-negative bacteria, accounting for 91.91% of the total number of pathogens. *Acinetobacter baumannii* (*A. baumannii*) was most common strain, accounting for 35.97% (378/1051) of the total strains, followed by *P. aeruginosa* (24.74%), *E. coli* (21.79%) and *Klebsiella pneumoniae* (*K. pneumoniae*) (9.42%). *S. aureus* was the most common Gram-positive bacteria strain with 8.09% (85/1051) (Table 2).

Drug-resistance trends and analysis of main pathogens

***A. baumannii*:** Resistance rates of *A. baumannii* to minocycline in 2017 and 2019 were 28.41% and 32.42%, respectively. Resistance rates of this strain to other antimicrobials were > 40% (Table 3). Energy allocation rate to the antimicrobial drug meropenem was 74.6%, and imipenem resistance rate was 75.66% (Table 4).

***E. coli*:** Carbapenem, piperacillin/tazobactam, amikacin, and cefoperazone/sulbactam showed inhibitory activity against *E. coli*. Analysis of 2019 data showed 21.4% (5/22) rate of resistance against cefotaxime and 13.6% (3/22) against tobramycin (Table 4). Resistance rate of *E. coli* against meroxifen was 14.41% (33/229), whereas resistance rate against imipenem was 15.28% (35/229) (Table 3).

***P. aeruginosa*:** In 2017, *P. aeruginosa* was generally resistant to a variety of antibiotics such as piperacillin/tazobactam, aminoglycosides, quinolones and carbapenem. Analysis of 2016, 2018 and 2019 data showed that a variety of antibiotics showed good antibacterial activity against *P. aeruginosa* (Table 4). Energy allocation rate of Meropenem against *P. aeruginosa* in the previous 4 years was 20.38% (53/260), whereas imipenem resistance rate was 26.5% (68/260) (Table 3).

***K. pneumoniae*:** Analysis of 2019 data showed that *K. pneumoniae* was 12.5% resistant to cefoperazone/sulbactam (3/27) and generally insensitive to other antibiotics. Drug resistance against *K. pneumoniae* in 2019 was severe compared with previous years (Table 4). Resistance rate of *K. pneumoniae* to Meropenem in the previous 4 years was 20.20% (20/99), whereas resistance rate of *K. pneumoniae* to imipenem was 19.9% (19/99) (Table 3).

***S. aureus*:** Incidence of methicillin resistance of *S. aureus* at the time of the study was 64.71% (55/85). In the previous 4 years, no resistance was recorded for linezolid and vancomycin antibiotics against *S. aureus* (Table 3).

Logistic regression analysis

A ratio of 1:1 was used to analyze risk factors for multidrug-resistant bacterial infection in 208 patients hospitalized in ICU with nosocomial infection. In addition, 208 patients hospitalized at the same time, and with comparable age, sex and symptoms were selected as a control group. Factors with $P \leq 0.05$ were included in the logistic regression model to avoid the influence of confounding factors. Logistic regression analysis showed that mechanical ventilation and urine tube intubation were risk factors for infection with multidrug-resistant bacteria (Tables 5 and 6).

DISCUSSION

ICU patients are in critical condition, and are often accompanied with multiple organ dysfunction and severe immune dysfunction. Ventilator and invasive operation may result in damage to physiological barriers of patients, and risk of infection in ICU patients is higher compared with patients in other departments[1]. ICU patients use antibiotics at a higher frequency, higher dose and longer duration, and

Table 1 Specimen type distribution and composition ratio in 2016-2019

Source of specimen	*n*	Proportion (%)
Sputum	1139	55.02
Blood	521	25.17
Drainage fluid	117	5.65
Urine	103	4.98
Peritoneal drainage fluid	72	3.48
Secretion	39	1.88
Bile	15	0.72
Cerebrospinal fluid	12	0.58
Pleural effusion	12	0.58
Ascites	3	0.14
Puncture fluid	3	0.14
Pus	2	0.10
Other	28	1.35
Catheter	4	0.19
Total	2070	100

Table 2 Distribution of pathogenic bacteria

Types of pathogens	*n*	Proportion (%)
Gram-negative bacteria		
A. baumannii	378	35.97
E. coli	229	21.79
P. aeruginosa	260	24.74
K. pneumoniae	99	9.42
Gram-positive bacteria		
S. aureus	85	8.09
Total	1051	100

A. baumannii: *Acinetobacter baumannii*; *E. coli*: *Escherichia coli*; *P. aeruginosa*: *Pseudomonas aeruginosa*; *K. pneumoniae*: *Klebsiella pneumoniae*; *S. aureus*: *Staphylococcus aureu*.

infection with multiple drug-resistant bacteria (multidrug-resistant organisms; MDROs) is severe compared with patients in other departments. Surveillance results of the European Centers for Disease Control and Prevention show that drug resistance of common pathogenic bacteria such as *A. baumannii* increased from 1997 to 2018[2]. Therefore, studies on nosocomial infections should be carried out. Intervention with drugs that are effective against drug-resistant pathogenic bacteria can reduce the incidence of MDROs. This study explored distribution of pathogens implicated in nosocomial infections in ICU and degree of drug resistance to a variety of antibiotics. The findings of this study will guide on rational use of drugs in clinics, to reduce the occurrence of drug-resistant bacteria. Furthermore, this study provides an effective scientific basis for improving clinical efficacy of antibiotics.

Antibiotics with a resistance rate > 40% to major pathogenic bacteria should be used cautiously. Antibiotics with a resistance rate > 50% to major pathogenic bacteria must be selected and used based on drug sensitivity test results. Use of antibiotics must be stopped if the drug resistance rate of the main pathogenic bacteria is > 75%. Feedback results of bacterial resistance must be investigated and analyzed, to determine whether clinical use of the drug can be continued. Therefore, it is important to explore detection and analysis of drug resistance of pathogenic bacteria in hospitals[3]. *A. baumannii* is a common cause of opportunistic infection in humans[4]. Drug-resistance and isolation rates of this strain have gradually increased in recent years with higher rates compared with the incidence of *P. aeruginosa*

Table 3 Main pathogens resistance rate in 2016-2019

	A. baumannii				*E. coli*				*P. aeruginosa*				*K. pneumoniae*				*S. aureus*			
	2016	2017	2018	2019	2016	2017	2018	2019	2016	2017	2018	2019	2016	2017	2018	2019	2016	2017	2018	2019
Amikacin	78.17	78.41	63.1	68.75	17.57	28.38	5.08	13.6	11.48	32.79	7.23	12.72	30.77	7.14	12.5	33.33	/	/	/	/
Aztreonam	/	/	/	/	45.95	51.35	30.51	40.9	/	/	/	/	26.92	21.43	34.38	51.85	/	/	/	/
Cefatriaxone	89.44	94.32	79.76	80.03	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Cefepime	81.69	78.57	72.62	80.95	48.65	48.65	16.95	22.7	14.75	45.9	13.25	18.18	/	/	/	/	/	/	/	/
Cefoperazone / sulbactam	61.27	60.71	48.81	68.4	25.68	29.73	5.08	21.4	9.84	19.67	8.43	12.2	/	/	/	/	/	/	/	/
Cefotaxime	88.73	94.32	77.38	77.3	74.32	66.22	44.07	21.4	/	/	/	/	/	/	/	/	/	/	/	/
Cefoxitin	/	/	/	/	54.05	54.05	37.29	50	/	/	/	/	/	/	/	/	/	/	/	/
Ceftazidime	82.39	77.27	71.43	81.25	/	/	/	/	21.31	27.87	13.25	21.82	38.46	21.43	34.38	55.56	/	/	/	/
Chloramphenicol	/	/	/	/	48.65	35.13	18.64	7.1	/	/	/	/	/	/	/	/	/	/	/	/
Ciprofloxacin	83.1	73.86	80.95	81.36	55.41	45.95	22.03	40.9	16.39	40.98	3.61	7.27	34.62	14.29	31.25	40.74	/	/	/	/
Clindamycin	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	82.76	70.83	35.71	50
Compound sulfanilamide	77.46	75	76.19	67.19	54.05	45.95	35.59	50	/	/	/	/	34.62	/	25	12.5	/	/	/	/
Gentamicin	/	/	/	/	55.41	45.95	27.12	45.5	/	/	/	/	42.31	14.29	15.63	29.26	89.66	66.67	7.14	25
Imipenem	81.69	62.5	75	85.54	24.32	22.97	/	/	26.23	45.9	15.66	20.75	26.92	14.29	3.13	34.61	/	/	/	/
Levofloxacin	/	/	/	/	52.7	44.59	22.03	31.8	18.03	34.43	6.02	7.27	34.62	21.43	31.25	40.91	67.86	37.5	/	/
Meropenem	78.87	67.05	77.38	72	24.32	20.27	/	/	19.67	40.98	9.64	14.55	26.92	21.43	3.13	33.33	/	/	/	/
Methicillin	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	100	41.2	57.1	50
Minocycline	78.17	28.41	59.52	32.42	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/
Moxifloxacin	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	/	79.31	70.83	/	/
Netilmicin	/	/	/	/	/	/	/	/	4.92	18.03	9.64	21.42	/	/	/	/	/	/	/	/
Piperacillin	/	/	/	/	/	/	/	/	24.59	47.54	13.25	21.82	/	/	/	/	/	/	/	/
Piperacillin / tazobactam	80.99	70.45	80.95	72.1	27.03	32.43	8.47	13.6	16.39	42.62	9.64	9.1	42.31	7.14	21.88	40.74	/	/	/	/
Ticarcillin / clavulanic acid	/	/	/	/	56.76	58.11	37.29	40.9	/	/	/	/	/	/	/	/	/	/	/	/
Tobramycin	83.8	78.57	76.19	81.36	52.7	45.95	30.51	13.6	18.03	39.34	8.43	12.09	38.46	7.14	15.63	40.91	/	/	/	/

A. baumannii: *Acinetobacter baumannii*; *E. coli*: *Escherichia coli*; *P. aeruginosa*: *Pseudomonas aeruginosa*; *K. pneumoniae*: *Klebsiella pneumoniae*; *S. aureus*: *Staphylococcus aureu*.

infections. *A. baumannii* was the main pathogen causing ICU colonization and nosocomial infection. Several studies have reported that *A. baumannii* is the most sensitive strain to imipenem. In addition, *A. baumannii* is highly sensitive to combination therapies of β-lactam and enzyme inhibitors such as cefoperazone/sulbactam and ampicillin/sulbactam. Sulbactam, an enzyme inhibitor, has direct antibacterial properties and an inhibitory effect against β-lactamases. Therefore, sulbactam is used in combination with cefoperazone and ampicillin. This strain is resistant to most antimicrobial agents and can be cloned and spread rapidly among strains. Surveillance data of drug resistance of CHINET bacteria in China in 2018 showed that resistance rates of imipenem and meropenem against this strain were 73.2% and 73.9%, respectively. In addition, resistance rates to cefoperazone/sulbactam and minocycline were 49.7% and 38.8% respectively. Resistance rates to polymyxin B and tigecycline were low (0.7% and 5.0%), whereas resistance rates to other tested drugs were > 40%. Resistance rate of *A. baumannii* to imipenem and meropenem significantly increased between 2005 and 2018. Resistance rates of 378 strains of *A. baumannii* isolated from ICU between 2016 and 2019 to imipenem and meroxifen were 75.66% and 74.6%, respectively. Resistance rates to cefoperazone/sulbactam during the 4 years were 61.27%, 60.71%, 48.81% and 68.4%, respectively. Further, resistance rates to quinolones in the 4 years were 83.10%, 73.86%, 80.95% and 81.36%, respectively. These rates were higher compared with rates recorded in data released in 2016 on sensitivity of bacteria to antimicrobial agents in CHINET in China. In addition, the report showed that rates of resistance to minocycline in 2017 and 2019 were 28.41% and 32.42% respectively. Notably, > 40% resistance rates to other antibiotics were recorded. These findings indicate that hospitals should monitor resistance of *A. baumannii* to a variety of antimicrobial agents in real time. Furthermore, mechanisms of antimicrobial resistance should be explored, accurate clinical use of antibiotics should be ensured, and infection control measures should be improved. These measures will prevent increases in multidrug resistance of *A. baumannii* to a variety of antibiotics thus reducing occurrence of multidrug-resistant strains[5].

E. coli infection in ICU patients is often serious, accompanied by multiorgan dysfunction and serious immune dysfunction. The rapid increase of infections caused by *Salmonella* and *K. pneumoniae* has become the current concern[6]. Previous studies have reported that uncontrolled use and abuse of carbapenem, third-and fourth-generation cephalosporins and quinolone antibiotics are independent risk factors for high incidence of multidrug-resistant bacteria[7]. Moreover, the strains showed high sensitivity to cefoperazone/sulbactam, amikacin, and piperacillin/tazobactam. Analysis of 2019 data showed that resistance rate of *E. coli* to cefotaxime and tobramycin was lower compared with previous years. These findings provide an important basis for hospital clinicians for choosing antibiotics. Hospital Enterobacteriaceae are used to study drug resistance of a variety of antimicrobials and rational use of antibiotics in clinical treatment.

P. aeruginosa was sensitive to a variety of antibiotics in 2016, 2018 and 2019. Energy allocation rates of imipenem and Meropenem resistance in the 4 years were 26.5% and 20.38%, respectively. This finding is important for clinicians when choosing antibiotics. Antibiotics with high sensitivity and low price should be selected based on characteristics and drug sensitivity of common infection pathogens in the ICU, to improve therapeutic effect and reduce economic burden of treatment to patients.

Table 4 Carbapenem-resistance rate against main Gram-negative bacteria

Antibiotics	*A. baumannii*	*E. coli*	*P. aeruginosa*	*K. pneumoniae*
Imipenem	75.66	15.28	26.15	19.19
Meropenem	74.6	14.41	20.38	20.2

A. baumannii: *Acinetobacter baumannii*; *E. coli*: *Escherichia coli*; *P. aeruginosa*: *Pseudomonas aeruginosa*; *K. pneumoniae*: *Klebsiella pneumoniae*.

Table 5 Data on patients with multidrug-resistant organisms in intensive care units

Factors		Patient group, *n* = 208	Control group, *n* = 208	t/χ^2	value
Gender, *n* (%)				2.648	0.104
	Male	105 (50.5)	98 (47.1%)		
	Female	103 (49.5)	110 (52.9%)		
Age				0.803	0.422
		67.71 ± 12.83	66.72 ± 12.31		
Operation experience, *n* (%)				0.471	0.492
		105 (50.5)	98 (47.1%)		
Total length of hospital stay				8.52	0.000
		27.13 ± 25.96	10.47 ± 11.06		
		20.96 ± 17.14	9.13 ± 9.52	8.707	0.000
Mechanical ventilation, *n* (%)					
		204 (98.1)	118 (56.7%)	101.65	0.000
Central venous catheterization, *n* (%)					
		180 (86.5)	161 (77.4%)	5.872	0.015
Urine tube intubation, *n* (%)					
		207 (99.5)	182 (87.5%)	24.755	0.000

Table 6 Risk factor analysis results

	B	SE	Wald	df	Sig.	Exp (B)	95%CI for Exp (B)	
							Lower	Upper
Mechanical ventilation	1.089	0.260	17.588	1	0.000	2.972	1.786	4.946
Urine tube intubation	0.816	0.195	17.424	1	0.000	2.261	1.542	3.317

CI: Confidence interval.

K. pneumoniae is commonly resistant against extended-spectrum β-lactamase and cephalosporin. Carbapenem antibiotics are some of the most effective for treatment of *K. pneumoniae* infection. In recent years, carbapenem-resistant *K. pneumoniae* has been widely spread around the world, resulting in a high resistance rate to almost all β-lactam antibiotics and increase in mortality. In 2013, the US Center for Disease Control and Prevention published threat of antibiotic resistance, including carbapenem-resistant Enterobacteriaceae as one of the three bacteria in the urgent threat category. In addition, in the 4 years, resistance rates of *K. pneumoniae* to imipenem and meropenem were 19.9% and 20.20%, respectively. The CHINET surveillance report shows that resistance rates of *K. pneumoniae* to meropenem and imipenem in 2013 were 13.5% and 10%, respectively. On the contrary, Enterobacteriaceae are highly sensitive to carbapenem antibiotics, however, drug resistance rate is gradually increasing. Previous studies have reported that infection with carbapenem-resistant *K. pneumoniae* causes a high number of in-hospital deaths[8,9]. Case fatality rate of *K. pneumoniae* infections, which is sensitive to carbapenem, is 25.7%. The case fatality rate of patients infected with carbapenem-resistant

K. pneumoniae is 50%, which is significantly higher compared with that of carbapenem-sensitive *K. pneumoniae*. Long-term use of central venous intubation is an independent factor for infections caused by carbapenem-resistant *K. pneumoniae*[10]. Restrictions on clinical use of broad-spectrum cephalosporins can effectively reduce resistance rate of *K. pneumoniae* to cephalosporins. Therefore, studies should explore characteristics of nosocomial infection of *K. pneumoniae*, analyze characteristics of antibiotic resistance, and implement rational distribution of antibiotics, to avoid further evolution of drug-resistant strains.

S. aureus is an important pathogen of nosocomial and community infection. The detection rate of multidrug-resistant *S. aureus* in a general hospital was approximately 65.82%[11]. No strains resistant to linezolid and vancomycin were detected among the strains isolated for the 4 years. Linezolid and vancomycin can be used to treat severe infection caused by Gram-positive cocci. However, widespread use of these antimicrobials will aggravate drug toxicity. These drugs can be used to prevent *S. aureus* resistance against vancomycin. Further studies should explore measures to control drug resistance against vancomycin[12]. Clinical management on use of antibiotics should be carried out, and vancomycin should not be used as the first choice for prevention and routine treatment of staphylococcal bacterial infections.

Logistic regression analysis showed that mechanical ventilation and urinary tube intubation were risk factors for infections caused by multidrug-resistant bacteria. This implies that medical staff should carefully consider the necessity before performing the above procedures., to reduce infections caused by multidrug-resistant bacteria. Mechanical ventilation, urinary catheterization and other invasive procedures increase point of entry for pathogens, thus increasing resistance level of multidrug-resistant bacteria. Therefore, the important task of preventing and controlling MDRO infection in the ICU is to improve the prevention and control measures as soon as possible, in the face of the increasing rate of multidrug-resistant infection worldwide[13].

CONCLUSION

Although bacteria have their own drug-resistance mechanism, the primary reason for high incidence of multidrug-resistant bacteria infection in ICUs is inappropriate use of antibiotics, especially abuse of third-generation cephalosporins[14-17]. Studies have reported that nosocomial infection in ICU patients is a major source of mortality. Adoption of clear evidence-based prevention and control methods to significantly reduce incidence of nosocomial infection is an important measure to improve treatment efficacy and prognosis of ICU patients. However, advocacy should be carried out to control nosocomial infection and reduce the rate of antibiotic resistance. The purpose of this study was to explore and analyze the main pathogens of ICU nosocomial infections and their drug resistance[18]. The study reports on main pathogenic bacteria of nosocomial infection and corresponding mechanism of drug resistance in the ICU at a specific time, and analyzed drug resistance of pathogenic bacteria after use of antibiotics in the same period. These findings provide a theoretical basis for hospital control of drug-resistant infections, so as to improve efficacy of antibiotics and safety of diagnosis and treatment of patients, rational use of antibiotics, and reduce pressure on patients, family members and the wider economy.

ARTICLE HIGHLIGHTS

Research background

There intensive care unit (ICU) patients are critically ill and have low immunity. They will undergo various trauma medical procedures during diagnosis and treatment. The use of high-dose hormones and broad-spectrum antibiotics will increase the incidence of nosocomial infection in ICU patients.

Research motivation

To explore the causes of nosocomial infection of multi drug resistant bacteria in ICU, and to provide basis for the prevention and control of nosocomial infection in ICU.

Research objectives

To provide basis for the prevention and control of nosocomial infection in ICU.

Research methods

BD PhoenixTM100 automatic bacterial identification and analysis instrument was used for cell identification. Inclusion criteria were: (1) The etiological diagnosis was multidrug-resistant bacterial infection; and (2) Inpatients in the ICU. Exclusion criteria were: (1) Diagnosis of multidrug-resistant bacterial colonization without clinical infection symptoms; (2) Contaminated samples of multidrug-resistant

bacteria; and (3) Natural resistant strains. Retrospective analysis was used to investigate and collect patient records and test data. Logistic regression analysis was used to perform univariate and multivariate analyses for independent risk factors for multidrug-resistant infection.

Research results

(1) Sample collection: The causative pathogens were mainly collected from sputum in 1139 cases (55.02%), blood in 521 (25.17%), and drainage in 117 (5.65%) (Table 1); (2) Distribution of pathogenic bacterial: *Acinetobacter baumannii* (*A. baumannii*) was most common strain, accounting for 35.97% (378/1051) of the total strains, followed by *Pseudomonas aeruginosa* (*P. aeruginosa*) (24.74%), *Escherichia coli* (*E. coli*) (21.79%) and *Klebsiella pneumoniae* (*K. pneumoniae*) (9.42%). *Staphylococcus aureus* (*S. aureus*) was the most common Gram-positive bacteria strain with 8.09% (85/1051) (Table 2); (3) Drug-resistance trends and analysis of main pathogens *A. baumannii*: Resistance rates of *A. baumannii* to minocycline in 2017 and 2019 were 28.41% and 32.42%, respectively. Resistance rates of this strain to other antimicrobials were > 40% (Table 3). Energy allocation rate to the antimicrobial drug meropenem was 74.6%, and imipenem resistance rate was 75.66% (Table 4); *E. coli*: Analysis of 2019 data showed 21.4% (5/22) rate of resistance against cefotaxime and 13.6% (3/22) against tobramycin (Table 4). Resistance rate of *E. coli* against meroxifen was 14.41% (33/229), whereas resistance rate against imipenem was 15.28% (35/229) (Table 3); *P. aeruginosa*: Analysis of 2016, 2018 and 2019 data showed that a variety of antibiotics showed good antibacterial activity against *P. aeruginosa* (Table 4). Energy allocation rate of meropenem against *P. aeruginosa* in the previous 4 years was 20.38% (53/260), whereas imipenem resistance rate was 26.5% (68/260) (Table 3); *K. pneumoniae*: Analysis of 2019 data showed that *K. pneumoniae* was 12.5% resistant to cefoperazone/sulbactam (3/27). Drug resistance against *K. pneumoniae* in 2019 was severe compared with previous years (Table 4). Resistance rate of *K. pneumoniae* to meropenem in the previous 4 years was 20.20% (20/99), whereas resistance rate of *K. pneumoniae* to imipenem was 19.9% (19/99) (Table 3); *S. aureus*: Incidence of methicillin resistance of *S. aureus* at the time of the study was 64.71% (55/85) (Table 3). And (4) Logistic regression analysis: A ratio of 1:1 was used to analyze risk factors for multidrug-resistant bacterial infection in 208 patients hospitalized in ICU with nosocomial infection. In addition, 208 patients hospitalized at the same time, and with comparable age, sex and symptoms were selected as a control group. Factors with $P \leq 0.05$ were included in the logistic regression model to avoid the influence of confounding factors. Logistic regression analysis showed that mechanical ventilation and urine tube intubation were risk factors for infection with multidrug-resistant bacteria (Tables 5 and 6).

Research conclusions

Although bacteria have their own drug-resistance mechanism, the primary reason for high incidence of multidrug-resistant bacteria infection in ICUs is inappropriate use of antibiotics, especially abuse of third-generation cephalosporins. Studies have reported that nosocomial infection in ICU patients is a major source of mortality. The purpose of this study was to explore and analyze the main pathogens of ICU nosocomial infections and their drug resistance. The study reports on main pathogenic bacteria of nosocomial infection and corresponding mechanism of drug resistance in the ICU at a specific time, and analyzed drug resistance of pathogenic bacteria after use of antibiotics in the same period.

Research perspectives

Logistic analysis results showed that mechanical ventilation and urinary tube intubation were risk factors for infections caused by multidrug-resistant bacteria. This finding implies that our medical staff should carefully consider the necessity before performing the above procedures, to reduce infections caused by multidrug-resistant bacteria. Mechanical ventilation, urinary catheterization and other invasive procedures increase point of entry for pathogens thus increasing resistance level of multi-drug-resistant bacteria. Therefore, the important task of preventing and controlling MDRO infection in ICU is to improve the prevention and control measures as soon as possible in the face of the increasing rate of multidrug-resistant infection in the world.

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FOOTNOTES

Author contributions: Han Y and Zhang J made equal contributions to the work; Han Y, Zhang J and Zhang HZ designed the study; Han Y, Zhang J, Zhang HZ, Wang YM, Zhang XY and Zhou XL studied; Zhang J and Zhang HZ analyze data and write articles; all authors have read and approved the final manuscript.

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