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Distribution and Risk Factors Analysis of Multidrug-resistant Bacterial Infections in ICU Ward Patients

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Abstract:

Objective: To analyze the distribution of multidrug-resistant bacteria and their related risk factors in patients in the intensive care unit (ICU) of hospitals. *Method:* A retrospective analysis was conducted on the clinical data of 902 inpatients admitted to the Intensive Care Unit (ICU) of Longquanyi District Traditional Chinese Medicine Hospital from October 2022 to October 2023. The ICU hospital obtained the distribution location of infectious pathogens and the characteristics of antibiotic resistance of infection-resistant bacteria. *Results:* Among the 902 hospitalized patients, 112 cases developed hospital-acquired infections, with an infection rate of 12.41%. A total of 168 strains of pathogenic bacteria were isolated from 112 hospital samples of infected patients. Among them, 28 cases were multidrug-resistant hospital infections, accounting for 16.67% of the total number of pathogenic bacteria. The types are carbapenem-resistant *Acinetobacter baumannii*, carbapenem-resistant *Klebsiella pneumoniae*, and carbapenem-resistant *Pseudomonas aeruginosa*, accounting for 46.42%, 28.57%, and 17.87%, respectively. Univariate analysis showed that long-term bed rest [1], nutritional risk, multiple hospitalizations within one year, systemic glucocorticoid use, duration of mechanical ventilation and ventilator use, duration of antibiotic use, the combination of antibiotics, duration of indwelling urinary catheters and indwelling catheters [2], duration of indwelling gastric catheters and indwelling catheters, duration of deep vein catheters and indwelling catheters, and length of ICU hospitalization were all influencing factors for the occurrence of hospital-acquired infections in the ICU. Multivariate analysis showed that mechanical ventilation, diabetes, length of ventilator use, length of ICU hospitalization and malignant tumors constituted independent risk factors for multidrug-resistant bacterial infection [3]. *Conclusion:* The infection rate of multidrug-resistant bacteria in ICU patients is high, and relevant prevention and control measures can be formulated based on their risk factors.

Keywords:

ICU
Multiple drug resistance
Hospital infection
Risk factor

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1. Materials and methods

1.1. General information

A total of 902 patients admitted to the Intensive Care Unit (ICU) of some hospitals in Longquanyi District between October 2022 and October 2023 were selected as subjects for a special investigation on the distribution of multidrug-resistant organism (MDRO) infections and their risk factors among ICU inpatients. Inclusion criteria for patients in the survey were ICU stay of ≥ 48 hours, patients who were not infected with MDRO at the time of admission, diagnosis of nosocomial infections referring to the "Hospital Infection Diagnostic Criteria (Trial)" [4], and complete clinical medical record data. Among the 902 patients included in this survey, there were 550 males and 352 females, with ages ranging from 31 to 99 (mean age: 65.69 ± 16.99 years old).

1.2. Methods and indicators

A retrospective analysis of the patients' clinical data was conducted, including general patient information, primary diseases, comorbidities such as chronic obstructive pulmonary disease (COPD) and coronary heart disease, whether patients were transferred after surgery, central venous catheter placement and indwelling time, urinary catheter insertion and indwelling time, ventilator use and duration, antimicrobial drug usage, duration of antimicrobial therapy, and whether antimicrobial drugs were used in combination, length of ICU stay, and whether glucocorticoids were administered. The purpose was to identify risk factors for MDRO infection. The identification of MDRO infection followed the guidelines outlined in the "Technical Guidelines for the Prevention and Control of Nosocomial Infections with Multi-Drug Resistant Organisms (MDROs) in China (Trial)."

1.3. Statistical methods

SPSS 26.0 statistical software was used for analysis. Measurement data that followed a normal distribution were described using mean ± standard deviation (SD) and compared using the two-sample *t*-test. Skewed data were described using median (M) and interquartile range (Q1, Q3) and analyzed using the Mann-Whitney U test. Count data were expressed as the number of cases (%) and compared using the chi-square test or Fisher's exact test. Multivariate logistic regression analysis was performed on variables with statistically significant differences in risk factors.

2. Results

2.1. Basic information

From October 2022 to October 2023, there were 902 hospitalized patients in the ICUs of some hospitals in Longquanyi District, among which 112 patients developed nosocomial infections, with an incidence rate of 12.41%. Among the patients with nosocomial infections, 28 cases of multi-drug resistant nosocomial infections were diagnosed, accounting for 16.67% of the total infection cases.

2.2. Distribution of infection samples

The main sources of ICU-acquired multidrug-resistant organism (MDRO) hospital infection samples are sputum, urine, and pleural/abdominal fluid, with a composition ratio of 53.58%, 14.29%, and 10.71%, respectively. The primary MDRO species infecting ICU patients are carbapenem-resistant *Acinetobacter baumannii*, carbapenem-resistant *Klebsiella pneumoniae*, and multidrug-resistant *Pseudomonas aeruginosa*, accounting for 46.42%, 28.57%, and 17.87%, respectively (**Table 1**).

2.3. Drug sensitivity analysis of multi-drug resistant bacteria

Carbapenem-resistant *Acinetobacter baumannii*, carbapenem-resistant *Klebsiella pneumoniae*, and carbapenem-resistant *Pseudomonas aeruginosa* are generally resistant to second and third-generation cephalosporins. Carbapenem-resistant *Acinetobacter baumannii* and carbapenem-resistant *Klebsiella pneumoniae* are sensitive to trimethoprim/sulfamethoxazole and tigecycline, while carbapenem-resistant *Pseudomonas aeruginosa* is sensitive to amikacin (**Table 2**).

2.4. Analysis of risk factors for infection

2.4.1. Univariate analysis

The results of the univariate analysis indicated that long-term bed rest, nutritional risk, diabetes, frequent hospitalizations within one year, systemic glucocorticoid

Table 1. Distribution of MDRO infection samples among ICU in-patients

Sample type	Carbapenem-resistant *Acinetobacter baumannii*	Carbapenem-resistant *Klebsiella pneumoniae*	Multidrug-resistant *Pseudomonas aeruginosa*	Others	Total
Sputum	9 (32.14)	5 (17.87)	3 (10.71)	1 (3.57)	18 (53.58)
Urine	2 (7.14)	1 (3.57)	1 (3.57)	0 (0.00)	4 (14.29)
Pleural/Abdominal fluid	0 (0.00)	2 (7.14)	1 (3.57)	0 (0.00)	3 (10.71)
Catheter	0 (0.00)	0 (0.00)	0 (0.00)	1 (3.57)	1 (3.57)
Secretion	1 (3.57)	0 (0.00)	0 (0.00)	0 (0.00)	1 (3.57)
Others	1 (3.57)	0 (0.00)	0 (0.00)	0 (0.00)	1 (3.57)
Total	13 (46.42)	8 (28.57)	5 (17.87)	2 (7.14)	28 (100)

Table 2. Drug resistance profile of major multi-drug-resistant bacteria

Antibacterial drug	Carbapenem-resistant *Acinetobacter baumannii* (*n* = 13)		Carbapenem-resistant *Klebsiella pneumoniae* (*n* = 8)		Carbapenem-resistant *Pseudomonas aeruginosa* (*n* = 5)	
	Number of resistant plants (*n*)	Drug resistance rate (%)	Number of resistant plants (*n*)	Drug resistance rate (%)	Number of resistant plants (*n*)	Drug resistance rate (%)
Ampicillin	13	100.00	8	100.00	5	100.00
Cefazolin	-	-	8	100.00	5	100.00
Gentamicin	13	100.00	8	100.00	0	0.00
Cefoxitin	13	100.00	8	100.00	-	-
Amikacin	13	100.00	8	100.00	0	0.00
Ceftriaxone	13	100.00	8	100.00	5	100.00
Ampicillin/Sulbactam	13	100.00	8	100.00	5	100.00
Trimethoprim/ Sulfamethoxazole	13	100.00	0	0.00	5	100.00
Piperacillin/Tazobactam	13	100.00	8	100.00	2	40.00
Cefuroxime	-	-	8	100.00	-	-
Meropenem	13	100.00	8	100.00	5	100.00
Cefepime	13	100.00	8	100.00	1	20.00
Levofloxacin	13	100.00	8	100.00	5	100.00
Ceftazidime	13	100.00	8	100.00	0	0.00
Aztreonam	13	100.00	8	100.00	5	100.00
Minocycline	0	0.00	8	100.00	5	100.00
Furantoin	13	100.00	8	100.00	-	-
Tigacycline	0	0.00	0	0.00	5	100.00
Colistin	13	100.00	8	100.00	0	0.00
Cefoperazone/Sulbactam	13	100.00	8	100.00	5	100.00
Amoxicillin/Clavulanic acid	-	-	8	100.00	-	-

use, duration of mechanical ventilation and ventilator use, duration of antimicrobial use, combination antibiotic therapy, indwelling urinary catheter and its duration, indwelling gastric tube and its duration, deep venous catheter placement and its duration, and length of ICU stay were predictive of drug-resistant bacterial infections in patients ($P < 0.05$) (**Table 3**).

2.4.2. Multi-factor analysis

Multi-factor logistic regression analysis was conducted on the variables selected through single-factor analysis. The results showed that mechanical ventilation (OR = 4.239, 95% CI: 1.092–36.186), nutritional risk (OR = 4.291, 95% CI: 1.091–23.065), duration of ventilator use (OR = 9.290, 95% CI: 1.116–1.659), length of ICU stay (OR = 14.196, 95% CI: 1.279–2.178), and malignant tumors (OR = 7.949, 95% CI: 5.345–11178.303) are independent risk factors for drug-resistant bacterial infections in ICU patients ($P < 0.05$) (**Table 4**).

Table 3. Univariate analysis results

Variable	MDRO group (n = 28)	Non-MDRO group (n = 84)	Significance (P)
Long-term bed rest (% of cases)	20 (71.4)	28 (33.3)	0.001
Nutritional risk (% of cases)	18 (64.3)	31 (36.9)	0.011
Diabetes (% of cases)	19 (67.9)	32 (38.1)	0.006
Malignant tumor (% of cases)	3 (10.7)	1 (1.2)	0.019
Number of hospitalizations in one year (mean ± SD, times)	2.07 ± 0.900	1.45 ± 1.366	0.027
Use of glucocorticoids (% of cases)	20 (71.4)	40 (47.6)	0.029
Mechanical ventilation (% of cases)	17 (60.7)	30 (35.7)	0.020
Duration of ventilator use (mean ± SD)	8.82 ± 4.627	2.86 ± 3.117	0.000
Indwelling urinary catheter (% of cases)	24 (85.7)	51 (60.7)	0.015
Indwelling gastric tube (% of cases)	21 (75.0)	45 (53.6)	0.046
Deep venous catheter placement (% of cases)	21 (75.0)	42 (50.0)	0.021
Duration of urinary catheter (mean ± SD)	10.25 ± 3.051	6.93 ± 5.703	0.004
Duration of gastric tube (mean ± SD)	4.61 ± 3.635	3.04 ± 2.818	0.020
Duration of deep venous catheter ≥ 1 week (% of cases)	26 (92.9)	46 (54.8)	0.000
Length of ICU stay (mean ± SD)	8.82 ± 3.422	5.26 ± 2.990	0.000
Duration of antimicrobial use (mean ± SD)	8.54 ± 4.069	5.44 ± 5.230	0.005
Combination antibiotic therapy (% of cases)	26 (92.9)	52 (61.9)	0.001

Table 4. Multi-factor logistic regression analysis

	Regression coefficient	Standard error	OR	95% CI	P value
Mechanical Ventilation	1.838	0.893	4.239	1.092–36.186	0.040
Nutritional risk	1.613	0.778	4.291	1.091–23.065	0.038
Duration of Ventilator use	0.308	0.101	9.290	1.116–1.659	0.002
Length of ICU stay	0.512	0.136	14.196	1.279–2.178	0.000
Malignant tumors	5.499	1.950	7.949	5.345–11178.303	0.005
Constant	-9.115	2.064	19.503	...	0.000

3. Discussion

ICU patients are critically ill and have low immunity, making them susceptible to nosocomial infections [5]. According to relevant literature, ICU inpatients have a significantly higher risk of developing nosocomial multidrug-resistant bacterial infections compared to other departments, and poor treatment outcomes can exacerbate the patient's condition, further leading to life-threatening situations [6]. Therefore, analyzing the distribution of multidrug-resistant bacterial pathogens and risk factors among ICU patients is extremely important for controlling the infection rate of multidrug-resistant bacteria in the ICU.

The results of this study show that the main sources of multidrug-resistant bacterial infection specimens are sputum and urine. The primary multidrug-resistant bacteria identified are carbapenem-resistant *Acinetobacter baumannii*, carbapenem-resistant *Klebsiella pneumoniae*, and carbapenem-resistant *Pseudomonas aeruginosa*. Overall, multidrug-resistant bacteria are mainly Gram-negative bacilli, which is consistent with the distribution characteristics of nosocomial infection pathogens [7]. Proper hand hygiene practices among healthcare workers, disinfection and isolation measures, and strict aseptic techniques during various procedures, especially invasive ones, play a crucial role in preventing multidrug-resistant bacterial infections [8]. Multivariate regression analysis identified mechanical ventilation, nutritional risk, duration of ventilator use, length of ICU stay, and malignancy as risk factors. ICU patients are often critically ill with multiple comorbidities, frequently including pulmonary diseases. Many of these patients undergo endotracheal intubation or tracheotomy and rely on mechanical ventilation for respiratory support [9]. As the duration of ventilation increases, so does the frequency of airway opening, elevating the risk of infection. Prolonged mechanical ventilation can lead to the formation of a biofilm in the respiratory tract, making bacteria more resistant to treatment. This may be attributed to invasive procedures disrupting the body's natural defense mechanisms, thereby increasing the vulnerability to pathogenic infections, particularly in the lungs [10–12]. Additionally, inadequate sterilization of equipment, non-standardized procedures, and insufficient aseptic techniques can all contribute to an increased risk of lung infections caused by drug-resistant bacteria. The use of suction catheters can damage the respiratory mucosal barrier, providing an entry point for pathogenic bacteria and further heightening the risk of drug-resistant bacterial lung infections. ICU patients, due to their severe conditions, often experience a decline in digestive system function, weakened digestive capacity, and compromised immune function. The use of anti-infective drugs frequently leads to gastrointestinal disorders and imbalances in intestinal flora, putting them at a higher risk of malnutrition [13]. Furthermore, infections can result in the depletion of albumin, and there is a positive correlation between hypoalbuminemia and the occurrence and severity of viral, bacterial, and fungal infections [14]. As ICU patients' length of stay increases, their immunity progressively weakens. Being exposed to a persistent environment of colonized bacteria makes them more susceptible to various pathogenic microorganisms, thereby increasing their infection risk [15]. Patients with malignant tumors, particularly those who have undergone radiotherapy and chemotherapy, have even lower immunity compared to general patients, further elevating their risk of infection [16].

4. Conclusion

In conclusion, the situation of multidrug-resistant bacterial infections in ICU wards is extremely severe. The distribution and drug resistance of these bacteria exhibit distinct characteristics and are influenced by a variety of factors. Patients with the aforementioned high-risk factors should undergo targeted screening and intervention. For those who have already developed infections, it is imperative to conduct proper isolation and identification of pathogenic bacteria, as well as drug resistance analysis. Antibiotics should be used rationally based on drug sensitivity results to prevent further increases in bacterial resistance. Healthcare workers must strictly adhere to disinfection measures before and after contact with patients, avoid unnecessary invasive procedures, strictly follow sterile practices during operations, and ensure timely disinfection of medical equipment. These efforts will create a favorable hospital environment for patients. Additionally, measures should be taken to reduce the duration of mechanical ventilation, improve

patients' nutritional status, supplement protein to maintain metabolic balance and enhance patients' immunity. These steps are aimed at achieving the goal of controlling multidrug-resistant hospital infections in the ICU.

Disclosure statement

The authors declare no conflict of interest.

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