



OPEN Analysis of antibacterial drug use and bacterial resistance in psychiatric hospital in the epidemic

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Analyze the use of antibacterial drugs and bacterial resistance in psychiatric hospital during the epidemic. Using the hospital information system and the National Antibacterial Drug Clinical Application Monitoring Network, we retrospectively collected data on the use of antibacterial drugs and bacterial resistance in psychiatric hospitals during the 2022 epidemic. During the 2022 epidemic, our hospital had an antibiotic use rate of 5.00%, a usage intensity of 3.07, a combined medication rate of 11.11%, a cumulative DDDs of 12,039.04, and antibiotic costs accounting for 3.95% of total drug costs. These are much lower than the levels in Jiangsu Province and nationwide. However, the rate of microbiological submission for antibacterial drug use was 77.78%, higher than that of Jiangsu Province and nationwide. The main antibiotics used in our hospital were third-generation cephalosporins, penicillins, and quinolone antibiotics, with the most commonly used being cefodizime, amoxicillin, and piperacillin–tazobactam. The results showed that Gram-negative bacteria mainly exhibited resistance to penicillins, cephalosporins, and quinolones, especially ampicillin, amoxicillin–clavulanic acid, ceftazidime, ceftriaxone, amikacin, and ciprofloxacin. Gram-positive bacteria mainly resisted penicillins, macrolides, and quinolones, especially penicillin, benzylpenicillin, erythromycin, levofloxacin, and ciprofloxacin. This study reveals a complex relationship between the rational use of antibacterial drugs and bacterial resistance in the psychiatric hospital. Although antimicrobial usage during the pandemic was generally appropriate, increased use in psychiatric settings correlated with rising bacterial resistance, thereby impacting treatment outcomes and patient prognosis. Therefore, it is recommended to enhance monitoring of bacterial resistance and regularly analyze resistance data to optimize antimicrobial use in psychiatric hospitals. This approach aims to ensure effective treatment while minimizing the development of resistant strains, ultimately improving the overall value of healthcare services.

Keywords COVID-19, Psychiatric hospital, Antibacterial drugs, Resistance rate, Gram-negative bacteria

As the novel coronavirus (COVID-19) continues to break out globally, it poses significant challenges to healthcare institutions worldwide. COVID-19 belongs to the β subtype of viruses, to which the general population is highly susceptible¹. Infections within medical institutions can lead to prolonged hospital stays, increased medical costs, and even fatalities in severe cases^{2,3}. Psychiatric hospitals, as critical and unique medical institutions, must address both the mental and physical health of patients.

The 2020 World Health Organization (WHO) report indicated that 8% of COVID-19 patients had bacterial co-infections, primarily involving *Streptococcus pneumoniae*, *Staphylococcus aureus*, *Haemophilus influenzae*, and *Pseudomonas aeruginosa*⁴. As the number of COVID-19 patients rises, it is essential to address bacterial infections and the importance of antibacterial treatments. However, the widespread use of broad-spectrum antibiotics has resulted in global concerns over misuse and improper use, leading to increased antibiotic resistance and the prevalence of multi-drug-resistant strains⁵. Patients with mental illnesses often lack self-care abilities and have weaker hygiene and self-protection awareness^{6,7}. Long-term use of antipsychotic drugs can lead to conditions like granulocytopenia or leukopenia, reducing the body's immunity and making them more susceptible to bacterial infections⁸. Moreover, psychiatric hospitals often employ a closed management system, with a high patient population participating in group activities, increasing the risk of infections^{9,10}. Thus, the use of antibacterial drugs plays a crucial role in the treatment of psychiatric hospital patients^{11–13}.

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During the epidemic, the use of antibacterial drugs in psychiatric hospitals has inevitably become a pressing issue. This study aims to analyze the usage of antibacterial drugs in psychiatric hospitals during the epidemic and to examine bacterial resistance patterns, providing a reference for rational clinical antibiotic use and infection control during the epidemic.

Materials and methods

Source of data

Data on the use of antibacterial drugs in 2022 from nationwide, Jiangsu Province, and our hospital was retrieved from the National Antibacterial Drug Clinical Application Monitoring Network (<http://y.chinadtc.org.cn/login>). Through the hospital information system, we extracted microbial test samples from our hospital in 2022, along with positive pathogen identification and drug sensitivity test data.

Methods

We employed a retrospective approach, using Excel to collect data on the rate of antibiotic use, antibiotic use intensity (AUD), combined medication rate, cumulative frequency of various types of antibiotic usage (DDDs), the percentage of antibiotic costs in total drug expenses, rate of microbiological submissions for antibiotics, and bacterial pathogen species and resistance patterns. Antibiotics (such as cefodizime, amoxicillin, and piperacillin–tazobactam) were among the most frequently used in terms of cumulative DDDs in 2022, based on the classification of antimicrobial agents by type. Our study follows the Clinical and Laboratory Standards Institute (CLSI) classification standards for multidrug-resistant (MDR) bacteria, with the primary categories being methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), extended-spectrum β -lactamase-producing bacteria (ESBLs), carbapenem-resistant Enterobacteriaceae (CRE), carbapenem-resistant *Pseudomonas aeruginosa* (CRPA), and multidrug-resistant *Acinetobacter baumannii* (MDRAB).

Statistical analysis

All data were analyzed descriptively using SPSS 20.0 software. Descriptive statistics were used to calculate frequencies (n) and percentages (%) for categorical variables, while continuous variables, such as the cumulative DDDs of antibiotics, were summarized using means where appropriate. T-tests were applied to assess differences between groups, and a significance threshold of $P < 0.05$ was considered statistically significant. Data were presented in tabular and graphical formats to facilitate comparison between our hospital's antimicrobial usage patterns and the reported provincial and national averages.

Results

Antibacterial drugs usage

In 2022, the antibiotic drug usage rate in our hospital was 5.00%, with a usage intensity of 3.07, cumulative DDDs of 12,039.04, and the antibiotic costs accounting for 3.95% of total drug expenses. These metrics are significantly lower than those of Jiangsu Province and the national levels (all $P < 0.01$). The combined medication rate in our hospital was 11.11%, which was significantly lower than that of Jiangsu Province ($P < 0.05$) but not significantly different from the national level ($P = 0.16$). The microbiological submission rate for antibacterial drug use in our hospital reached 77.78%. Although higher than the levels in Jiangsu Province and nationwide, the differences were not statistically significant ($P > 0.05$) (Fig. 1).

Accumulated DDDs of various types of antibiotics

Based on the classification of antibiotics, the accumulated DDDs in 2022 were mainly from third-generation cephalosporins (74.61%), penicillin class+enzyme inhibitors (9.52%), penicillin antibiotics (7.15%), and quinolone antibiotics (6.15%). By antibiotic variety ranking, the accumulated DDDs in 2022 mainly consisted of cefodizime (74.41%), amoxicillin (7.15%), and piperacillin–tazobactam (5.27%) (Fig. 2).

Bacterial resistance status

In 2022, our hospital submitted 5,373 specimens for testing. Of these, 2,737 positive bacterial strains were isolated, with a positive rate of 50.94%. The majority were Gram-negative bacteria, primarily *Pseudomonas aeruginosa* (23.20%), *Escherichia coli* (22.43%), and *Klebsiella pneumoniae* (15.45%). Among the key multi-drug-resistant bacteria detected, *Staphylococcus aureus* in Gram-positive strains had the highest proportion of resistance (70.69%), followed by *Acinetobacter baumannii* (59.26%) (Table 1).

Research has shown that the Gram-negative bacteria in our hospital primarily show high resistance rates to penicillin, cephalosporins, and quinolones. For instance, *Pseudomonas aeruginosa* has a 100% resistance rate to tetracyclines, ampicillin, amoxicillin–clavulanate, ceftriaxone, and ertapenem. Drugs with a resistance rate exceeding 50% include compound neomycin (66.46%) and tigecycline (66.46%). *E. coli* demonstrates a high resistance rate to cephalosporins (50.68%) and quinolones (73.53%), including specific drugs like ampicillin (92.92%), cefazolin (80.71%), ceftriaxone (77.91%), amikacin (75.29%), levofloxacin (72.31%), and ciprofloxacin (74.76%). *K. pneumoniae* shows high resistance to penicillins (57.31%) and quinolones (50%), including specific drugs like ampicillin (100%), cefazolin (60.16%), ceftriaxone (56.65%), amikacin (58.12%), and ciprofloxacin (54.83%). *Acinetobacter baumannii* displays high resistance to penicillins (95.77%), cephalosporins (70.42%), and carbapenems (57.84%), with specific drugs like ampicillin, amoxicillin–clavulanate, cefazolin, and amikacin all having a 100% resistance rate. Drugs with a resistance rate exceeding 50% include piperacillin–tazobactam (57.14%), ticarcillin–clavulanate (50.00%), cefepime (58.73%), ceftriaxone (59.77%), imipenem (59.26%), and ciprofloxacin (60.85%) (Table 2).

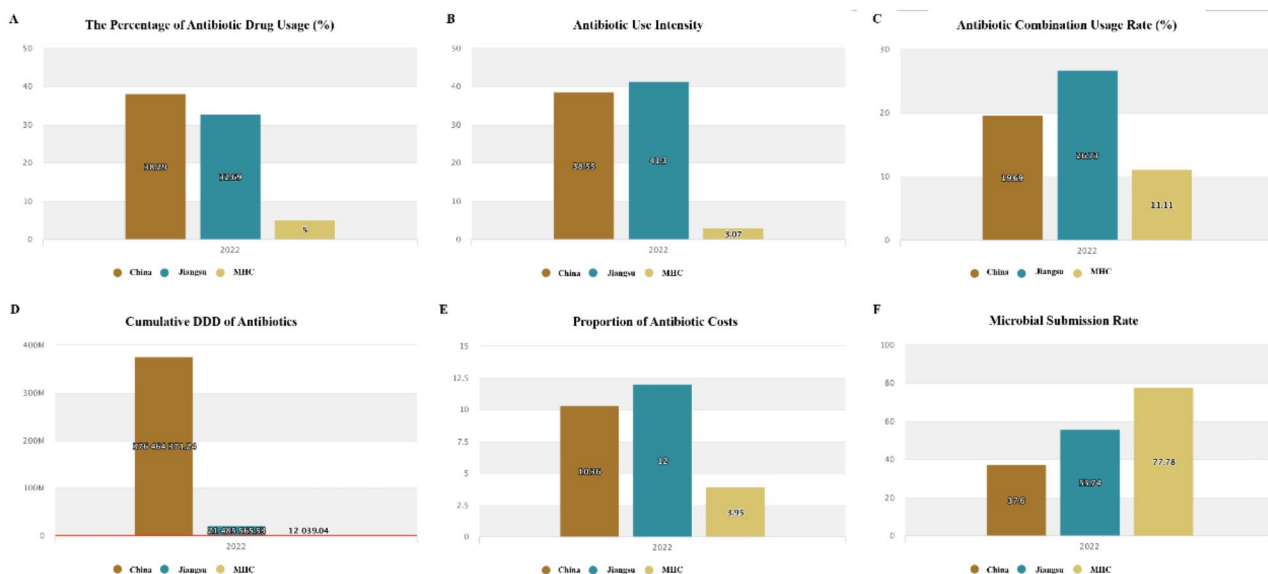


Fig. 1. Antibacterial Drugs Usage. (A) The percentage of antibiotic drug usage (%); (B) Antibiotic use intensity; (C) Antibiotic combination usage rate (%); (D) Cumulative DDD of antibiotics; (E) Proportion of antibiotic costs; (F) Microbial submission rate. *Note* Compared to Jiangsu Province and the national average, MHC has lower rates of antimicrobial usage, intensity of use, combination medication rate, cumulative DDDs, and proportion of antimicrobial costs. However, the microbiological submission rate is higher.

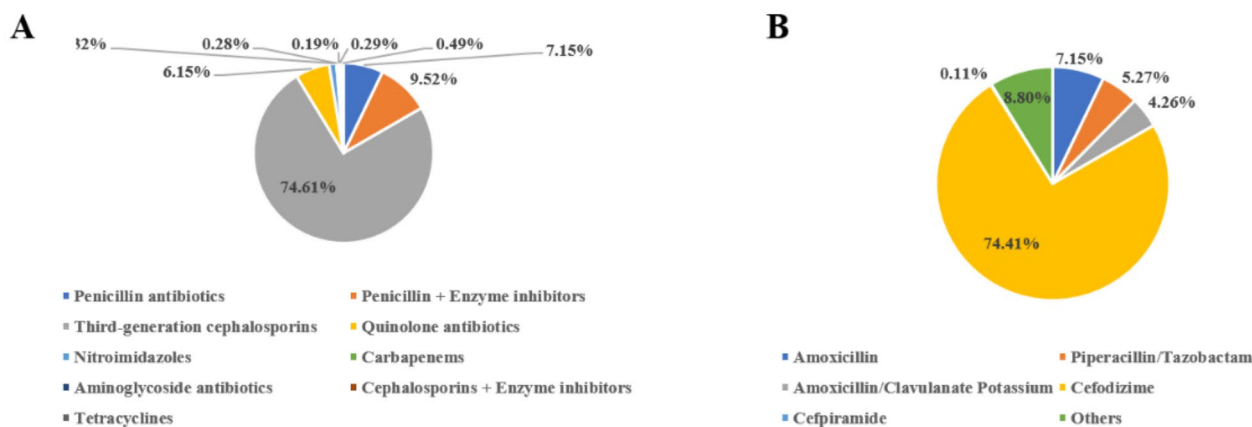


Fig. 2. Accumulated DDDs of various types of antibiotics. (A) The percentage of classification of antibiotics; (B) By antibiotic variety ranking.

Category	Bacterial name	Total strains (n)	Percentage (%)	Multi-drug resistant strains (n)	Multi-drug resistant percentage (%)
Gram-negative	<i>Pseudomonas aeruginosa</i>	635	23.20	199	31.34
	<i>Escherichia coli</i>	614	22.43	26	4.23
	<i>Klebsiella pneumoniae</i>	423	15.45	127	30.02
	<i>Acinetobacter baumannii</i>	189	6.91	112	59.26
Gram-positive	<i>Staphylococcus aureus</i>	58	2.12	41	70.69

Table 1. Monitoring of multi-drug resistant bacteria in our hospital in 2022.

Among Gram-positive bacteria, *Staphylococcus aureus* has a high resistance rate to penicillins (82.76%), macrolides (53.45%), and quinolones (47.70%); resistance rates exceeding 50% were observed for penicillin, benzylpenicillin, erythromycin, levofloxacin, and ciprofloxacin. The resistance rate for vancomycin is low (1.79%), and no resistant strains were found for nitrofurantoin, linezolid, tigecycline, and rifampin (Table 3).

Antibacterial drugs	<i>Pseudomonas aeruginosa</i> (%)	<i>Escherichia coli</i> (%)	<i>Klebsiella pneumoniae</i> (%)	<i>Acinetobacter baumannii</i> (%)
Penicillin Class	41.33	38.22	57.31	95.77
Piperacillin/Tazobactam	14.56	5.54	30.71	57.14
Ticarcillin/Clavulanic Acid	32.17	37.50	25.00	50.00
Ampicillin	100.00	92.92	100.00	100.00
Amoxicillin/Clavulanic Potassium	100.00	17.38	41.94	100.00
Cephalosporins Class	25.94	50.68	46.62	70.42
Cefepime	9.29	26.47	35.51	58.73
Cefoperazone/Sulbactam	21.74	0.00	25.00	21.43
Cefazolin	37.80	80.71	60.16	100.00
Ceftriaxone	100.00	77.91	56.65	59.77
Ceftazidime	–	14.82	34.95	–
Other β -lactams, Aztreonam	–	75.29	58.12	100.00
Carbapenems Class	22.69	4.00	29.06	57.84
Imipenem	22.71	4.08	28.98	59.26
Ertapenem	100.00	4.07	28.88	–
Meropenem	18.60	0.00	25.00	42.86
Aminoglycosides Class	4.62	25.15	30.44	47.38
Tobramycin	5.20	30.78	36.03	47.09
Gentamicin	6.90	42.33	36.27	47.70
Amikacin	2.99	2.93	19.11	–
Tetracycline Class	100.00	25.00	25.00	17.86
Doxycycline	100.00	37.50	25.00	28.57
Minocycline	100.00	12.50	25.00	7.14
Quinolones Class	24.57	73.53	50.00	48.15
Levofloxacin	25.35	72.31	45.17	35.45
Ciprofloxacin	23.78	74.76	54.83	60.85
Nitrofurans, Nitrofurantoin	–	0.68	41.76	–
Compound Sulfamethoxazole	66.46	49.10	37.08	46.03
Glycopeptides Class, Teicoplanin	66.46	0.00	11.18	3.72
Polymyxin	9.28	6.25	0.00	0.00

Table 2. Drug resistance rate of Gram-negative bacteria. Gram-negative bacteria exhibit high resistance rates to penicillins, cephalosporins, and quinolone antibiotics. *Pseudomonas aeruginosa* shows 100% resistance to tetracyclines, ampicillin, amoxicillin–clavulanate, ceftriaxone, and ertapenem; *Klebsiella pneumoniae* is 100% resistant to ampicillin; and *Acinetobacter baumannii* shows 100% resistance to ampicillin, amoxicillin–clavulanate, cefazolin, and aztreonam.

Discussion

During the epidemic in 2022, our hospital had an antimicrobial usage rate of 5.00%, an intensity of 3.07, a combination medication rate of 11.11%, a cumulative DDDs of 12,039.04, and antimicrobial expenses accounting for 3.95% of the total drug costs. The antibiotic usage rate in our hospital is lower than the rates reported in studies^{14–16}, and it meets the national guidelines for the Clinical Application of Antimicrobial Agents¹⁷ and the Notice on Further Strengthening the Special Rectification of Clinical Use of Antimicrobial Agents Nationwide¹⁸, which set a target of $\leq 5\%$ for psychiatric hospitals. In line with these policies, our hospital has actively implemented strict antibiotic management measures, such as enhancing the monitoring and evaluation of antimicrobial usage, providing training for medical staff to raise awareness of rational drug use, and promoting the rational use of antibiotics through multidisciplinary collaboration. Additionally, psychiatric patients often have other underlying conditions and complex medical needs, which may also lead to a more cautious approach to antibiotic use. Our hospital had a microbial submission rate for antimicrobial usage of 77.78%, higher than the levels in Jiangsu province and nationally, complying with the requirements of the Notice on Further Strengthening the Special Rectification of Clinical Use of Antimicrobial Agents Nationwide (2011) that the microbial submission rate before using antimicrobial agents should be $\geq 30\%$ ¹⁹. These results indicate that our hospital's antimicrobial usage during the epidemic was generally rational, in line with the requirements for psychiatric clinical practice, and essentially provided appropriate antibiotic treatment for patients. However, it's crucial to further strengthen the supervision, publicity, and training on the rational use of antimicrobials to enhance medical staff awareness about the proper use of antimicrobials and prevent misuse.

DDDs reflect the frequency of antimicrobial use. A higher DDD indicates a greater preference for that drug or category of drugs. During the epidemic, our hospital mainly used third-generation cephalosporins (74.61%), penicillin+enzyme inhibitors (9.52%), penicillin antibiotics (7.15%), and quinolone antibiotics (6.15%). Cefotaxime (74.41%) was the most used, followed by amoxicillin (7.15%) and piperacillin–tazobactam

Antibacterial drugs	Staphylococcus aureus (%)
Penicillin Class	82.76
Benzylpenicillin (Penicillin G)	70.69
Penicillin	94.83
Aminoglycosides, Gentamicin	22.41
Tetracycline Class, Tetracycline	15.52
Macrolides, Erythromycin	53.45
Glycopeptides, Vancomycin	1.79
Lincosamides, Clindamycin	39.66
Quinolones Class	47.70
Levofloxacin	50.00
Ciprofloxacin	50.00
Moxifloxacin	43.10
Nitrofurans, Nitrofurantoin	0.00
Folic Acid Metabolism Inhibitors, Compound Sulfamethoxazole	6.90
Oxazolidinones, Linezolid	0.00
Glycopeptides, Teicoplanin	0.00
Ansamycins, Rifampicin	0.00

Table 3. Drug resistance rate of gram-positive bacteria. Gram-positive bacteria exhibit high resistance rates to penicillins, macrolides, and quinolone antibiotics.

(5.27%). The 2022 WHO Global Antimicrobial Resistance and Use Surveillance System (GLASS) report showed that broad-spectrum penicillin and third-generation cephalosporins were the most commonly used. During the epidemic, respiratory infections, especially upper respiratory infections, were predominant in psychiatric specialties, primarily treated with penicillin and cephalosporin antibiotics¹⁷. Among the cephalosporins, third-generation cephalosporins have a stronger antibacterial effect against most G- bacteria than the first and second generations, making them a more popular choice in clinical settings.

Related to antibiotic resistance in 2022 revealed that out of 5,373 samples submitted, 2,737 strains of bacteria tested positive, a positivity rate of 50.94%. The majority were Gram-negative bacteria, consistent with many studies^{20,21}. *Pseudomonas aeruginosa* (23.20%), *Escherichia coli* (22.43%), and *Klebsiella pneumoniae* (15.45%) were among the most common. Gram-negative bacteria showed high resistance rates to penicillins, cephalosporins, and quinolones. The most drug-resistant antibiotics include ampicillin, amoxicillin–clavulanate, ceftiozime, ceftriaxone, norfloxacin, and ciprofloxacin. Gram-positive bacteria were primarily resistant to penicillins, macrolides, and quinolones, with high resistance rates against penicillin, benzylpenicillin, erythromycin, levofloxacin, and ciprofloxacin.

This study found that although the overall antibiotic usage in our hospital is relatively low, certain antibiotics are used excessively, mainly cephalosporins, penicillins and their enzyme inhibitors, and quinolones. Among these, cefodizime is used the most, followed by amoxicillin, piperacillin–tazobactam, and others. This correlates with the high antibiotic resistance rates of Gram-negative and Gram-positive bacteria in our hospital. The excessive frequency of use of these antibiotics is likely contributing to the generally high resistance rates. In addition to drug usage, environmental factors and infection control policies in psychiatric settings can indeed contribute to resistance. The closed environment and high-density patient gatherings in psychiatric hospitals increase the risk of infection transmission. Psychiatric patients generally have longer hospital stays, and some may be uncooperative, allowing resistant bacteria to spread rapidly through contact. This is an important factor in the increase in resistance rates²². Environmental factors, such as water sources, air quality, and surface cleanliness, may also affect the spread of resistant bacteria. Infection control strategies, including hand hygiene, isolation measures, and appropriate disinfection and cleaning protocols, are crucial to reducing the spread of resistant bacteria; strengthening infection monitoring and control policies can help limit their transmission²³.

Additionally, psychiatric patients may suffer from other physical illnesses, which could increase their demand for antibiotics, especially in the treatment of complex infections. Furthermore, the immune systems of psychiatric patients may be weakened, and some psychiatric medications may affect their immune function, reducing their ability to resist infections and making them more susceptible to resistant bacteria²⁴. Therefore, besides medication, environmental factors, infection control policies, and patients' health status are all worth attention. To effectively address this issue, psychiatric hospitals need to adopt comprehensive measures, including strict infection control policies, rational antibiotic management, and education for both patients and healthcare workers, to reduce the development and spread of resistance.

Conclusion

This study offers an in-depth analysis of the use of antimicrobial agents and bacterial resistance in psychiatric specialty hospitals during the pandemic. It was found that the use of antimicrobials during the pandemic was generally reasonable. However, as the use of antimicrobials in psychiatric specialty hospitals increased, so did the rate of bacterial resistance. Therefore, there is a need to strengthen the management of antimicrobial use

in psychiatric specialty hospitals including drug sensitivity testing and tailored antibiotic protocols based on resistance data, enhance the monitoring of bacterial resistance, and rationally select antimicrobials with low resistance rates based on drug sensitivity test results to reduce the occurrence of bacterial resistance. This study contributes to improving antibiotic management and reducing bacterial resistance in psychiatric specialty hospitals, providing experience and strategies for the rational use of antimicrobials in these settings. Measures include enhancing monitoring systems by developing and implementing regular surveillance of antibiotic usage and resistance patterns, which can collect and analyze data, identify trends, and adjust antibiotic strategies in a timely manner. Regular educational training for patients and healthcare staff on the importance of correct antibiotic use is also essential. Establishing a mechanism for periodic review of antibiotic prescribing patterns and setting up a dedicated antibiotic stewardship team to evaluate the appropriateness of prescriptions and provide feedback ensures that all antibiotic prescriptions undergo strict scrutiny. Implementing strict infection control policies, such as hand hygiene, environmental disinfection, and isolation measures, reduces the risk of bacterial and resistant strain transmission. Finally, promoting multidisciplinary collaboration among pharmacists, infectious disease specialists, and psychiatrists helps ensure the rationality and effectiveness of antibiotic use.

Data availability

The dataset generated during and analyzed during the current study are available from the corresponding author on reasonable request.

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Author contributions

Zhiqiang Du and Haohao Zhu conceived the study; Ying Jiang, Rongrong Lu, Qin Zhou, Yuan Shen and Mengmeng Ou collected the report; Ying Jiang, Zhiqiang Du and Haohao Zhu wrote the manuscript and edited the

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Declarations

Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

All experimental protocols were approved by Wuxi Mental Health Center. The ethics approval and informed consent have been waived by the Ethics Committee of Wuxi Mental Health Center. All methods were performed in accordance with relevant guidelines and regulations.

Additional information

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