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ORIGINAL RESEARCH

Role of Antimicrobial Stewardship in Modulating Antibiotic Use and Mitigating Bacterial Resistance in a Tertiary Care Setting During COVID-19

Xueyan Zhang[1,*], Lijuan Zhou[1,*], Pingzhi Peng[2], Weiquan Zhang[2], Chunhong Liang[2]

[1]Department of Pharmacy, Sixth Affiliated Hospital of Guangxi Medical University, Yulin, Guangxi, 537000, People's Republic of China; [2]Office of Drug Clinical Trial Institution, Sixth Affiliated Hospital of Guangxi Medical University, Yulin, Guangxi, 537000, People's Republic of China

*These authors contributed equally to this work

Correspondence: Chunhong Liang, Office of Drug Clinical Trial Institution, Sixth Affiliated Hospital of Guangxi Medical University, Yulin, Guangxi, 537000, People's Republic of China, Tel +86-15778671091, Email lchhon@163.com

Purpose: Despite the widespread adoption of antimicrobial stewardship (AMS) programs, their effectiveness varies because of differing regional policies and socioeconomic factors. This study aimed to assess the impact of AMS at a Chinese tertiary care hospital on inpatient antimicrobial use and bacterial resistance during the COVID-19 outbreak.

Methods: An interrupted time-series regression analysis was conducted to compare inpatient antimicrobial use between pre- and post-intervention periods. The Chi-squared test and linear regression analysis were used to compare bacterial resistance and illustrate temporal trends in bacterial resistance, respectively.

Results: Following the AMS strategy implementation, we observed a significant decrease in antimicrobial consumption at unrestricted ($\beta 2 = -6.38$, $P = 0.004$), restricted ($\beta 2 = -17.81$, $P < 0.001$), and special levels ($\beta 2 = -2.32$, $P < 0.001$). Despite a reduction in the use of third-generation cephalosporins and macrolides ($\beta 2 = -6.85$, $P < 0.001$; $\beta 2 = -2.82$, $P < 0.001$), an increase in the trend of use was observed post-intervention ($\beta 3 = 0.15$, $P < 0.001$; $\beta 3 = 0.04$, $P = 0.001$). Methicillin resistance in *Staphylococcus aureus* significantly decreased ($\beta = -0.23$, $P < 0.001$) from 52.85% to 40.92%. Conversely, the prevalence of carbapenem-resistant *Klebsiella pneumonia* increased from 4.69% to 10.87% ($P < 0.001$), whereas resistance to *Acinetobacter baumannii* and *Pseudomonas aeruginosa* marginally decreased ($P<0.05$). We observed decreases in the antimicrobial utilization rate ($\beta 2 = -11.86$, $P = 0.003$) and combination utilization rate ($\beta 2 = -12.36$, $P = 0.011$) post-intervention. No significant changes in special-level antimicrobial and prophylactic agent use in category I incisional surgeries were observed.

Conclusion: An AMS program in a Chinese tertiary facilitated effective management of antimicrobial use and reduction of bacterial resistance during the COVID-19 pandemic, in the context of combined infection prevention and control measures. The findings provide useful insights for the implementation of antimicrobial stewardship in future public health crises.

Keywords: public health, antimicrobial management, healthcare strategy, COVID-19

Introduction

Excessive and inappropriate antimicrobial use is a key driver of antimicrobial resistance (AMR), a major global public health threat causing profound socioeconomic issues.[1] Globally, antibiotic consumption and AMR are escalating at alarming rates, with global per-capita antibiotic consumption increasing by 46% from 2000 to 2018.[2] Moreover, an estimated 4.71 million deaths were associated with bacterial AMR in 2021 alone.[3]

Since the 1990s, an increasing number of nations have implemented antimicrobial stewardship (AMS) programs,[4] with approximately 90% of countries currently possessing an AMR national action plan.[5] AMS programs have effectively reduced the incidence of antibiotic-resistant bacteria by promoting minimal antibiotic use;[5,6] however, their efficacy and implementation vary widely because of differences in local policies, healthcare delivery systems, and socioeconomic factors.

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The COVID-19 pandemic severely impacted societal structures and compromised efforts in healthcare infection prevention and control.[7] Between 2020 and 2022, global pharmaceutical sales data revealed a positive correlation between antibiotic use and COVID-19 cases, which was attributed to the overuse and misuse of antibiotics for COVID-19 treatment.[8] Additionally, the pandemic likely hastened the development and spread of AMR, particularly among gram-negative bacteria in hospital settings.[9–11] Findings from a meta-analysis involving over 30,000 patients indicated that three-quarters of those with COVID-19 were prescribed antibiotics, a figure significantly higher than the 8.6% estimated prevalence of bacterial co-infection,[12] highlighting the ongoing need for AMS research in the context of COVID-19.

The World Health Organization (WHO) approved a Global action plan and monitoring framework for infection prevention and control (IPC) for 2024–2030 in 2024, based on the profound lessons learned from major outbreaks such as H1N1, Ebola virus disease, and COVID-19. The framework emphasizes that antimicrobial stewardship should be integrated into patient care pathways and policy systems alongside IPC interventions.[13] Accordingly, the present study examined the impact of AMS implementation in a tertiary hospital on bacterial resistance and antimicrobial usage during the COVID-19 pandemic. The hospital did not merely adhere to government-led infection prevention and control measures during the COVID-19 epidemic, as contrasted with previous research practices,[14,15] but also actively implemented a series of innovative and comprehensive AMS strategies throughout the hospital. We believe that our findings will assist healthcare facilities in improving the management of antimicrobial drugs and controlling bacterial resistance during significant public health emergencies.

Materials and Methods

Study Design and Setting

This study was conducted at the Sixth Affiliated Hospital of Guangxi Medical University, a comprehensive tertiary hospital with 2600 available beds in Guangxi, China. The hospital emphasizes the AMS organizational style and implements multidisciplinary collaborative management of antimicrobial drugs based on administrative intervention. The professional AMS team, composed of the Medical, Pharmacy, Infection Management, Laboratory, and Information Departments, has played an active role in standardizing the use of clinical antimicrobial drugs and reducing irrational medication use. In December 2019, as the COVID-19 pandemic began in China, the team implemented a plan detailed in documents such as "Normalized Management of Antimicrobial Drug Intensity" to regulate the use of antibiotics by inpatients.

The impact of AMS during the COVID-19 epidemic was evaluated by conducting a comparative analysis of changes in bacterial resistance and antimicrobial usage prior to and following the intervention, in the context of combined infection prevention and control measures. To account for the time required for the AMS strategy and COVID-19 to take effect, the intervention (interruption) time point was set to January 2020. The intervention period spanned from January 2020 to March 2023, while the pre-intervention period encompassed January 2017 to December 2019.

Data Collection

The impact of the AMS intervention was predominantly evaluated through antimicrobial consumption, interpreted as antimicrobial use density (AUD), bacterial resistance rate, and several other management indicators for antimicrobial applications, including antimicrobial utilization rate, combination utilization rate, special-level antimicrobial drug utilization rate, and the proportion of antimicrobial agents used for prophylaxis in category I incisional surgery. These metrics were obtained from the hospital information system. Data on antibacterial consumption for the overall, unrestricted-use, restricted-use, and special-use classes were expressed as DDDs/100 patient-days in accordance with the guidelines for Anatomical Therapeutic Chemical (ATC) classification and DDD assignment 2023.[16] Resistance rates were expressed as the percentage of resistant isolates among all tested isolates. Antimicrobial susceptibility was evaluated based on the Clinical and Laboratory Standards Institute (CLSI) Performance Standards for Antimicrobial Susceptibility Testing (M100-2023).[17] Isolates that exhibited intermediate resistance were excluded from this investigation. During the same hospital stay, duplicate test results from the same patient were kept isolated from each other.[18]

Antimicrobial Classification Principles

The Guiding Principles for Clinical Application of Antimicrobials 2015 released by China clearly classifies antibiotics into unrestricted-, restricted-, and special-use levels.[19] Antimicrobials in the unrestricted-use category have been clinically demonstrated to be safe and effective in the long term, have a low impact on antimicrobial resistance, and are relatively inexpensive. In contrast, although restricted use antimicrobials have also been demonstrated to be safe and effective, they have a greater impact on antimicrobial resistance or are relatively expensive. Special-use antimicrobials have one of the following characteristics. They have significant or serious adverse reactions that require cautious use, potent and broad-spectrum antimicrobial activity, and high cost. In addition, frequent use can easily lead to pathogen resistance; clinical data on efficacy and safety are lacking and require further verification.

Intervention

Administrative control and multidisciplinary collaborative management were employed to implement the AMS program during the COVID-19 pandemic, balancing clinical requirements and management objectives. This implementation included five key measures: (1) targeting AUD stewardship values by department, where monthly AUD target stewardship values for each department were determined by integrating historical data, national assessment targets, and antimicrobial consumption in institutions with comparable care levels; (2) intensive training and publicity to strengthen the specialty through training sessions, lectures, knowledge contests, and other promotional activities to enhance comprehension and proficiency in the judicious utilization of antibiotics; (3) regular antibiotic prescription audits and monthly feedback (audits of 200–400 inpatient antibiotic records) conducted by physicians and clinical pharmacists from the Rational Drug Usage Guidance Expert Group; (4) automatic AUD alerts, updated in real-time by the Hospital Information System (HIS) and announced monthly by the Office Automation System; and (5) linking assessment results with performance, in which clinical departments reduced their monthly AUD by 1 DDD/100 patient-days below the target receive incentives, whereas penalties, such as deductions and the suspension of prescribing privileges, may be imposed for exceeding the target or arbitrary application.

Statistical Analysis

Analyses were performed using IBM SPSS Statistics 23 for Windows (IBM Corp., Japan, Tokyo, Japan). Statistical significance was set at $P < 0.05$. The Chi-squared test was employed to compare quarterly bacterial resistance between the pre-intervention and post-intervention periods. Furthermore, linear regression analysis was used to elucidate trends in bacterial resistance over time. Interrupted time-series (ITS) analyses were performed to identify the effect of intervention on the monthly AUD of antibiotics and other indicators of rational antimicrobial use. The model included baseline outcome values (β_0), baseline trends (β_1), level changes following the intervention (β_2), and trend changes after the intervention (β_3). Residual analysis was performed to test for serial autocorrelation, and autocorrelation was assessed using the Durbin–Watson (DW) statistic, with DW values near two indicating the absence of autocorrelation.

Results

Segmented Regression Analysis of Monthly Antibiotic Consumption

The segmented regression analysis results and monthly antibiotic consumption trends are depicted in Table 1 and Figure 1. In the ITS analysis of total antibiotics, total antibiotic use declined prior to the AMS intervention ($\beta_1 = -0.24$, $P = 0.020$). Following the intervention, an upward trend ($\beta_3 = 0.47$, $P = 0.001$), accompanied by a significant decrease in the level of use ($\beta_2 = -26.53$, $P < 0.001$), was observed.

The ITS analysis of antibiotics with varying grades revealed a downward trend in restricted-use antibiotic utilization before the intervention ($\beta_1 = -0.30$, $P < 0.001$). The intervention decreased consumption levels for unrestricted-use ($\beta_2 = -6.38$, $P = 0.004$), restricted-use ($\beta_2 = -17.81$, $P < 0.001$), and special-use antibiotics ($\beta_2 = -2.32$, $P < 0.001$). Nevertheless, consumption of restricted ($\beta_3 = 0.37$, $P = 0.001$) and special ($\beta_3 = 0.06$, $P < 0.001$) antibiotics exhibited upward trends during the intervention period. No significant variations in trend were observed in the unrestricted-use level before and after the intervention.

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Table 1 Segmented Regression Analysis Results Comparing Antibiotic Use Before and After the Antimicrobial Stewardship Intervention

Antimicrobial Class	DW	Baseline Level (β_0)		Baseline Trend (β_1)		Level Change (β_2)		Trend Change (β_3)	
		Coefficient (95% CI)	*P*-value	Coefficient (95% CI)	*P*-value	Coefficient (95% CI)	*P*-value	Coefficient (95% CI)	*P*-value
Total antibiotics	2.14	47.01(42.78,51.24)	<0.001	−0.24(−0.44,-0.04)	0.020	−26.53(−37.48,-15.58)	<0.001	0.47(0.20,0.73)	0.001
Antimicrobial grade									
Unrestricted use level	2.14	13.04(11.41,14.68)	<0.001	0.04(−0.03,0.12)	0.267	−6.38(−10.61,-2.15)	0.004	0.04(−0.06,0.14)	0.456
Restricted use level	1.80	32.39(29.03,35.74)	<0.001	−0.30(−0.45,-0.14)	<0.001	−17.81(−26.49,-9.12)	<0.001	0.37(0.16,0.58)	0.001
Special level	1.50	1.65(1.31,2.00)	<0.001	0.01(−0.01,0.03	0.166	−2.32(−3.20,-1.43)	<0.001	0.06(0.04,0.08)	<0.001
ATC categories									
Carbapenems	2.18	2.58(1.84,3.31)	<0.001	−0.01(−0.04,0.03)	0.860	−0.18(−2.07,1.72)	0.855	0.01(−0.03,0.06)	0.546
β-lactams and β-lactamase inhibitors	2.10	22.33(16.39,28.28)	<0.001	−0.01(−0.28,0.28)	0.976	3.72(−11.67,19.11)	0.631	−0.15(−0.52,0.23)	0.442
Third-generation cephalosporins	1.60	7.15(6.51,7.80)	<0.001	−0.10(−0.13,-0.07)	<0.001	−6.85(−8.53,-5.18)	<0.001	0.15(0.11,0.19)	<0.001
Quinolones	2.27	11.34(9.31,13.36)	<0.001	−0.19(−0.29,-0.10)	<0.001	−2.45(−7.68,2.78)	0.353	0.13(0.01,0.26)	0.050
Tetracyclines	1.86	0.35(0.02,0.68)	0.040	0.01(−0.01,0.03)	0.118	0.49(−0.38,1.35)	0.265	−0.02(−0.04,0.01)	0.126
Macrolides	1.66	4.13(3.73,4.53)	<0.001	−0.06(−0.08,-0.04)	<0.001	−2.82(−3.86,-1.79)	<0.001	0.04(0.02,0.07)	0.001
Glycopeptides	2.27	0.29(0.12,0.46)	0.001	0.01(−0.01,0.01)	0.316	−0.19(−0.63,0.25)	0.386	0.01(−0.01,0.02)	0.377

Abbreviations: CI, confidence interval; DW, Durbin–Watson; ATC, Anatomical Therapeutic Chemical.

In the ITS analysis of antibiotics with ATC categories, third-generation cephalosporins (β_1 = −0.10, *P* < 0.001), quinolones (β_1 = −0.19, *P* < 0.001), and macrolides (β_1 = −0.06, *P* < 0.001) exhibited downward trends prior to the intervention. However, the level of the use of third-generation cephalosporins and macrolides significantly decreased (β_2 = −6.85, *P* < 0.001; β_2 = −2.82, *P* < 0.001), while the trend increased (β_3 = 0.15, *P* < 0.001; β_3 = 0.04, *P* = 0.001) post-intervention. The usage of carbapenems, β-lactams and β-lactamase inhibitors, tetracyclines, and glycopeptides remained stable throughout the study.

Changes in Bacterial Resistance

Figure 2, Supplementary Table S1, and Table 2 illustrate the proportions of carbapenem resistance in gram-negative bacteria and methicillin resistance in *Staphylococcus aureus* measured quarterly. Figure 2 and Supplementary Table S1 present the overall trend of antibiotic resistance over the years. Methicillin-resistant *S. aureus* demonstrated a significant

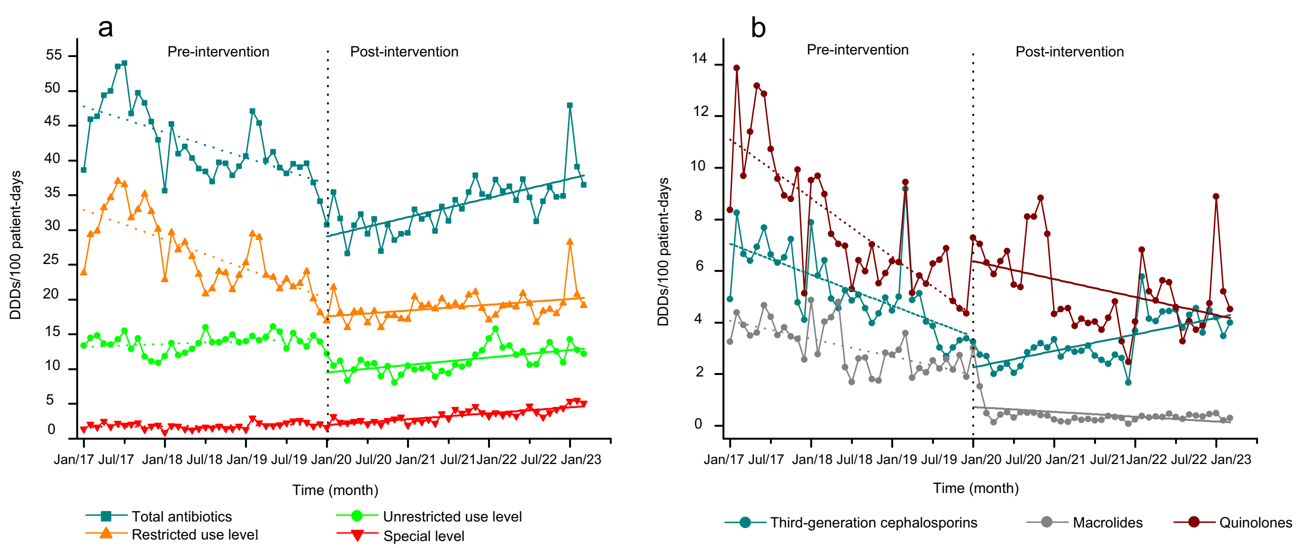

Figure 1 Changes in monthly antibiotic use before and after the antimicrobial stewardship intervention. (**a**) Changes in antibiotic use with total and varying grades. (**b**) Changes in antibiotic use with ATC categories. Dashed line: regression line before the intervention. Solid line: regression line following the intervention.
Abbreviation: ATC, Anatomical Therapeutic Chemical.

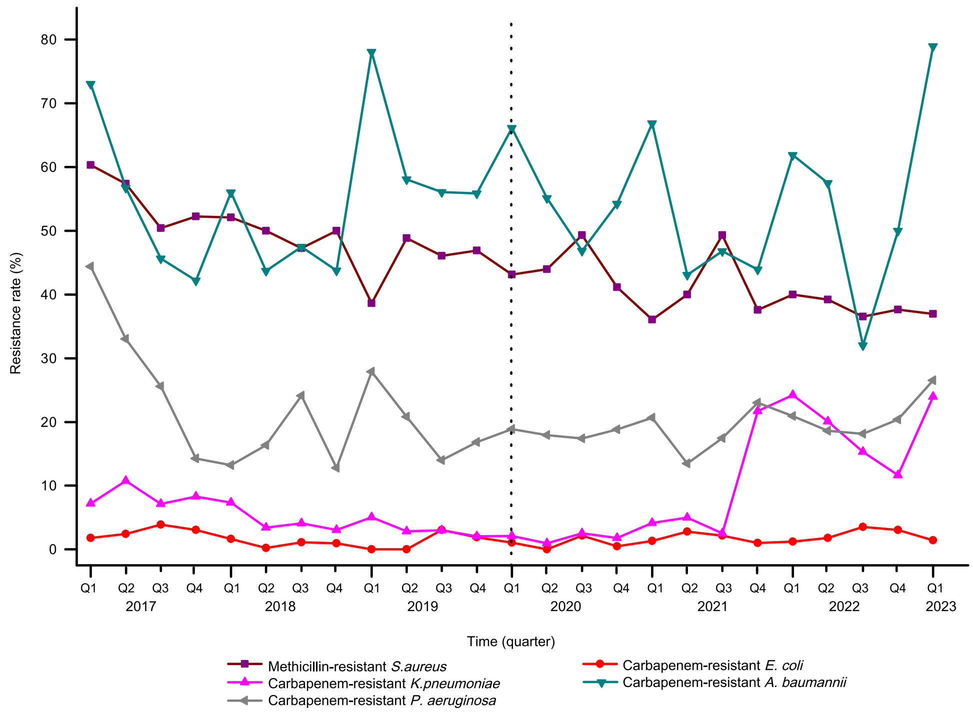

Figure 2 Trends of carbapenem resistance in gram-negative bacteria and methicillin resistance in *S. aureus* for the entire study period.

decrease in resistance rate ($\beta = -0.23$, $P < 0.001$) over the years, with rates considerably lower in the post-intervention period than in the pre-intervention period (40.92% vs 52.85%; $P < 0.001$) (Table 2). Conversely, the prevalence of carbapenem-resistant *Klebsiella pneumoniae* increased substantially ($\beta = 0.13$, $P = 0.008$), from 4.69% prior to the intervention to 10.87% following the intervention ($P < 0.001$) (Table 2). The overall trend of carbapenem resistance did not significantly differ among *Acinetobacter baumannii, Pseudomonas aeruginosa*, and *Escherichia coli* during the study period ($P > 0.05$). However, the resistance rates of *A. baumannii* (53.56% vs 56.66%; $P = 0.026$) and *P. aeruginosa* (19.24% vs 21.34%; $P = 0.012$) decreased in the post-intervention period compared with those in the pre-intervention period (Table 2).

Changes in Additional Management Indicators for Antimicrobial Applications

Figure 3 and Table 3 illustrate segmented regression analyses of monthly data in hospitalized patients regarding the antimicrobial utilization rate, combination utilization rate, special-level antimicrobial drug utilization rate, and proportion of antimicrobial agents used for prophylaxis in category I incisional surgery. Antimicrobial utilization rate ($\beta_1 = -0.18$, $P = 0.016$) and combination utilization rate ($\beta_1 = -0.28$, $P = 0.002$) trends exhibited decreases during the pre-intervention period in hospitalized patients. Following the AMS intervention, the antimicrobial utilization rate ($\beta_2 = -11.86$, $P = 0.003$) and combination utilization rate ($\beta_2 = -12.36$, $P = 0.011$) decreased. Additionally, the combination utilization

Table 2 Bacterial Resistance Rates Before and After the Intervention

	Pre-intervention Period		**Post-intervention Period**		***P*-value**
Methicillin-resistant *S. Aureus*	52.85%	(1354/2562)	40.92%	(1400/3421)	<0.001
Carbapenem-resistant *E. Coli*	1.47%	(92/6262)	1.67%	(140/8360)	0.325
Carbapenem-resistant *K. Pneumoniae*	4.69%	(194/4140)	10.87%	(671/6173)	<0.001
Carbapenem-resistant *A. Baumannii*	56.66%	(1514/2672)	53.56%	(1295/2418)	0.026
Carbapenem-resistant *P. Aeruginosa*	21.34%	(804/3768)	19.24%	(1156/6008)	0.012

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

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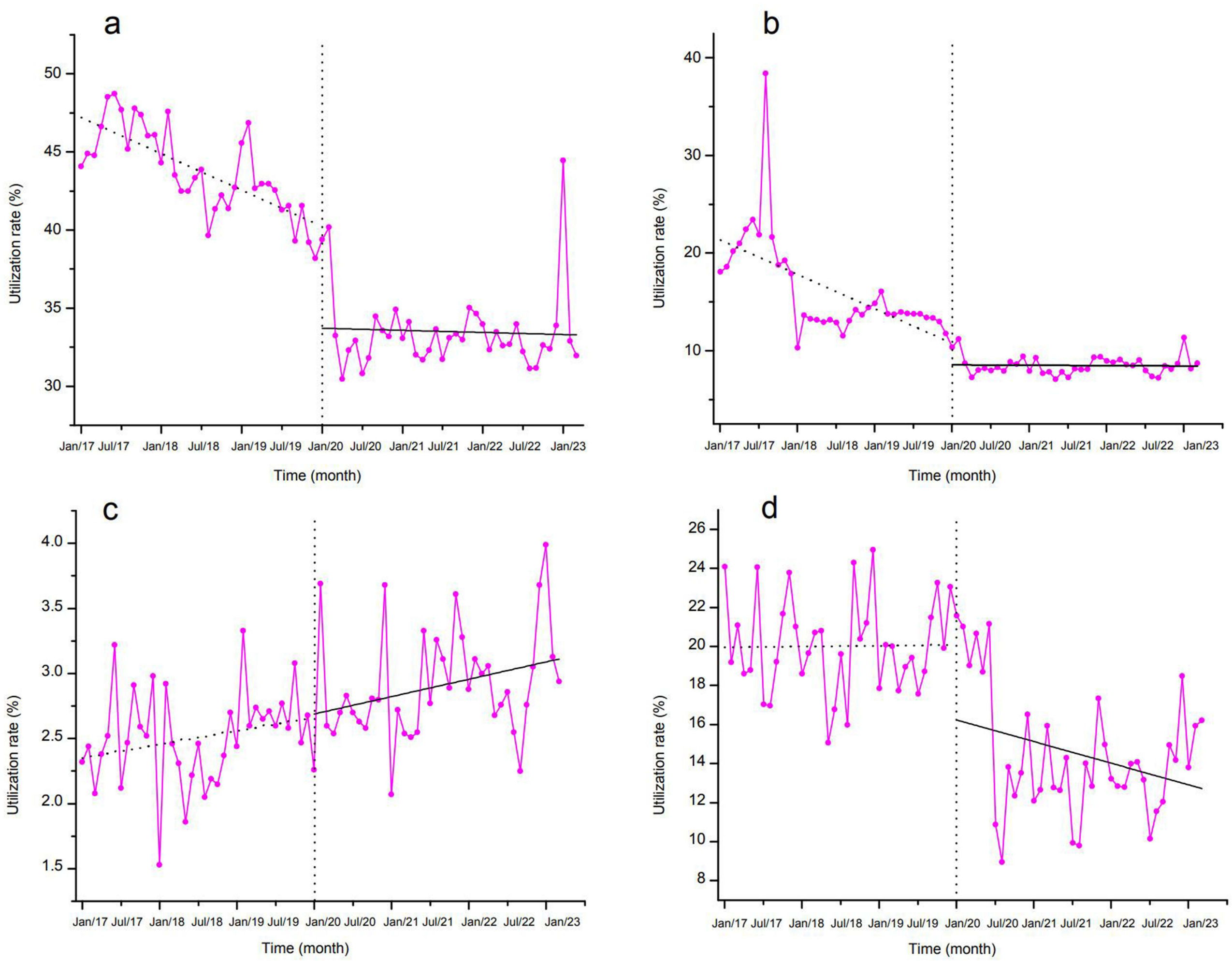

Figure 3 Changes in several management indicators for antimicrobial applications before and after the antimicrobial stewardship intervention. (**a**) Antimicrobial utilization rate (**b**) Antimicrobial combination utilization rate (**c**) Special-level antimicrobial utilization rate (**d**) Antimicrobial agent use rate for prophylaxis in category I incisional surgery. Dashed line: regression line before the intervention. Solid line: regression line following the intervention.

rate demonstrated an upward trend ($\beta_3 = 0.27$, $P = 0.024$). No significant changes occurred in the trend in the use of special-level antimicrobial drug or in the use of antimicrobial agents for prophylaxis in category I incisional surgeries.

Discussion

The aim of the present study was to evaluate the role of an antimicrobial stewardship program in modulating antibiotic use and mitigating bacterial resistance at a tertiary hospital during the COVID-19 pandemic, in the context of extensive government-led infection prevention and control measures. Inpatient antimicrobial consumption, utilization rate, and combination utilization rate decreased after implementation of the intervention, as did the detection rates of methicillin-resistant *S. aureus*, carbapenem-resistant *A. baumannii*, and *P. aeruginosa*.

According to the WHO, antibiotic overuse was widespread during the COVID-19 pandemic. Although only 8% of hospitalized patients with COVID-19 had bacterial co-infections, approximately 75% received antibiotics as a precaution.[-20] Nevertheless, our ITS analysis revealed significant reduction in overall antibiotic use within three specific categories compared with that during the pre-intervention period. Additionally, the intervention led to lower rates of inpatient antimicrobial use and combination therapy. The positive changes are partly due to the AMS intervention, which aims to optimize antibiotic prescription practices and reduce unnecessary antimicrobial consumption.[21] They also reflect the synergistic effect of combining AMS with infection prevention and control measures during the unique period of the epidemic. The Chinese government instituted rigorous isolation and protection measures, such as home confinement and

Table 3 Segmented Regression Analysis for Several Additional Management Indicators for Antimicrobial Applications

Management Indicator	DW	Baseline Level (β_0)		Baseline Trend (β_1)		Level Change (β_2)		Trend Change (β_3)	
		Coefficient (95% CI)	*P*-value	Coefficient (95% CI)	*P*-value	Coefficient (95% CI)	*P*-value	Coefficient (95% CI)	*P*-value
Antimicrobial utilization rate (%)	2.20	47.19 (44.18,50.19)	<0.001	−0.18 (−0.32, −0.03)	0.016	−11.86 (−19.64,-4.09)	0.003	0.15 (−0.04,0.34)	0.128
Antimicrobial combination utilization rate (%)	2.28	21.55 (17.91,25.19)	<0.001	−0.28 (−0.45,-0.11)	0.002	−12.36 (−21.79,-2.93)	0.011	0.27 (0.04,0.50)	0.024
Special-level antimicrobial utilization rate (%)	1.98	2.34 (2.08,2.61)	<0.001	0.01 (−0.01,0.02)	0.170	−0.07 (−0.76,0.61)	0.830	0.01 (−0.01,0.02)	0.760
Antimicrobial agent use rate for prophylaxis in category I incisional surgery (%)	2.33	20.50 (16.83,24.17)	<0.001	−0.02 (−0.20,0.15)	0.793	1.24 (−8.27,10.74)	0.796	−0.11 (−0.34,0.13)	0.369

Abbreviation: CI, confidence interval.

social distancing, to effectively control the spread of the virus during the COVID-19 pandemic.[22] Demand for medications may have shifted to retail pharmacies following a decrease in hospital service availability, demonstrating the impact of public health policies on medical behavior and antimicrobial use.[23,24]

Antibiotics may not benefit patients with COVID-19 who do not have bacterial co-infection. Instead, they may potentially lead to higher mortality rates and longer hospitalization periods.[25,26] However, in response to the urgency of treating patients, concerns regarding COVID-19 co-infections with bacteria, and ambiguity regarding clinical issues, healthcare professionals may adjust their prescription behaviors and increase antibiotic use.[27] Patients with COVID-19 were also more likely to receive high-level antibiotics, classified as "watch" and "reserve" in the WHO AWaRe (access, watch, and reserve) classification.[26,28] This partly explains why, despite the overall decline in antibiotic consumption during the COVID-19 pandemic in the present study, the consumption of β-lactams and β-lactamase inhibitors, carbapenems, and glycopeptides was not affected significantly by the intervention. However, we observed an increasing trend in the use of macrolides and third-generation cephalosporins, highlighting that the use of some antibiotics is still a challenge and that there is an urgent need to evaluate and optimize antibiotic use in the patient population with COVID-19.

The COVID-19 pandemic postponed years of progress in the United States in the fight against AMR, according to a report from the Centers for Disease Control and Prevention.[29] Notably, the detection rates of methicillin-resistant *S. aureus*, carbapenem-resistant *A. baumannii*, and *P. aeruginosa* decreased when compared with those during the pre-pandemic period, similar to the findings of Li et al, who reported a substantial decline in antimicrobial-resistant rates following the pandemic and AMS implementation.[15] The implementation of AMS may reduce the spread of bacterial drug resistance resulting from the COVID-19 pandemic by reducing the unreasonable use of antibacterial drugs. Additionally, the implementation of more stringent infection prevention and control measures, such as hand hygiene, surface disinfection, and social distancing, became more widespread among the public as a consequence of COVID-19, which may account for a portion of the decline in bacterial resistance.[30] In contrast, the substantial increase in the detection rate of carbapenem-resistant *K. pneumoniae* following the COVID-19 pandemic is a cause for concern. Characterizing this patient population may be necessary to identify specific risk factors associated with the development of drug resistance.

We observed no significant change in the trends and levels of antimicrobial agent use rate for prophylaxis in category I incisional surgery. Substantial decrease in surgical activity and increase in postoperative antimicrobial prescriptions were observed during the pandemic compared with during the previous and subsequent years.[31] Use of surgical-associated antimicrobials during a pandemic remains critical as healthcare personnel are wary of serious complications amid pandemic demands,[32] which may influence surgical antimicrobial practices.

We acknowledge some limitations of the present study. First, the generalizability of our results may be limited because they are based on data from a single tertiary hospital. Resistance trends and patterns of antimicrobial use can vary among healthcare facilities of different sizes and regions. Second, the consistency and comparability of the findings could have been affected by variations in AMS program implementation across different organizations. Additionally, our AMS practices are not specific to outbreaks, even though anti-infective therapy for COVID-19 follows standardized guidelines. Further research should be conducted to examine the long-term effects of AMS on antimicrobial use and resistance, as well as the ongoing use of AMS programs to support the changing healthcare environment. Furthermore, we did not evaluate the individual contributions of COVID-19 infection control policies and the AMS program, rendering it challenging to determine which factor had the most significant impact on bacterial resistance and antimicrobial use.

Conclusion

In conclusion, according to our findings, an AMS program in a Chinese tertiary hospital facilitated effective management of antimicrobial use and reduction of bacterial resistance during the COVID-19 pandemic, in the context of combined infection prevention and control measures. The findings provide useful insights for the implementation of antimicrobial stewardship in future public health crises.

Data Sharing Statement

The datasets used and/or analyzed in the current study are available from the corresponding author upon reasonable request.

Ethics Approval

This study was reviewed and approved by the Ethical Committee of Sixth Affiliated Hospital of Guangxi Medical University (Approval No. 2024089). Informed consent was waived by the ethics committee as all the data were obtained from the hospital as routine work and not for the present study. In addition, the data did not include patient-specific information. Furthermore, the research was conducted in accordance with the Declaration of Helsinki.

Consent for Publication

Obtained.

Author Contributions

All authors made a significant contribution to the work reported, whether in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all the areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no competing interest in this work.

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