Antimicrobial Stewardship & Healthcare Epidemiology (2025), **5**, e244, 1–7
doi:10.1017/ash.2025.10155

SHEA

Original Article

Clinical pharmacist-led Antimicrobial Stewardship under volume-based procurement: a retrospective quasi-experimental study on rational use and resistance control

Yan He[1], Haini Jiang[2], Guangjie Wu[1], Wei Li[1], Lu Wang[1], Lin Gui[1], Wenting Zhang[1], Dong Xu[3], Li Tan[4], Zhongju Chen[5], Xuepeng Gong[1], Jianhong Wu[2] and Dong Liu[1]

[1]Department of Pharmacy, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China, [2]Department of Medical Affairs, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China, [3]Department of Infection Disease, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China, [4]Department of Hospital Infection Management, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China and [5]Department of Microbiology Laboratory, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China

Abstract

Background: Antimicrobial resistance (AMR) is a global health crisis exacerbated by policies like China's Volume-Based Procurement (VBP), which may inadvertently increase antimicrobial overuse. This study evaluates a clinical pharmacist-led Antimicrobial Stewardship (AMS) program with prospective audit for special-restricted antimicrobials under VBP.

Methods: A retrospective quasi-experimental interrupted time-series analysis compared pre-intervention (2022) and post-intervention (2023–2024) data at Tongji Hospital, a tertiary hospital in Wuhan, China. Key metrics included Antimicrobial Use Density (AUD), prescription rationality, antimicrobial costs, and multidrug-resistant infection rates.

Results: The intervention significantly improved prescription appropriateness for special-restricted antimicrobials (80.24% vs. 93.83%, $P < 0.005$) and reduced AUD (47.87 vs. 34.25, $P < 0.001$). Total antimicrobial costs decreased by 41.26%, with a reduction in the incidence of multidrug-resistant infections from 0.084% to 0.062% ($P < 0.05$). Carbapenem use correlated with CRKP isolation rates ($R = 0.62$, $P < 0.05$). Clinical pharmacists rejected 10.24% of prescriptions, all accepted by physicians.

Conclusion: Pharmacist-led prospective audits optimize antimicrobial use under VBP, mitigate resistance risks, and reduce costs, while acknowledging that concurrent infection control measures may have contributed to these trends. This model may inform similar interventions in other institutions, particularly those in resource-limited settings.

(Received 28 May 2025; accepted 15 August 2025)

Introduction

Antimicrobial resistance (AMR) represents a critical global public health crisis.[1,2] In response, Antimicrobial Stewardship (AMS) programs have become essential interventions to mitigate AMR progression and optimize therapeutic outcomes.[3] The evolving role of pharmacists—transitioning from traditional drug dispensing to active engagement in patient-specific pharmacotherapy—has been increasingly recognized in AMS frameworks.[4] International guidelines now explicitly endorse pharmacists as pivotal contributors to AMS, with organizations such as the Infectious Diseases Society of America (IDSA) and the Centers for Disease Control and Prevention (CDC) advocating for pharmacist leadership or co-leadership in these initiatives to enhance clinical outcomes.[5–7] Similarly, the Royal Pharmaceutical Society highlights pharmacists' expertise in delivering evidence-based antimicrobial optimization strategies.[8]

Clinical benefits of pharmacist-integrated AMS are well-documented.[9–12] The multinational EUROBACT-2 cohort study demonstrated that pharmacist consultations reduced 28-day mortality rates in ICU patients with hospital-acquired bloodstream infections (adjusted OR: 0.62; 95% CI: 0.41–0.93).[9] While China's three-tier antimicrobial classification management system (established in 2004) has effectively standardized the clinical use of restricted-use antimicrobials (classified as Reserve group antibiotics under the WHO AWaRe framework), [13–15] the implementation of the Volume-Based Procurement (VBP) policy in 2018 introduced new challenges for managing these agents.[16] The VBP policy utilizes a "volume-for-price" negotiation model to

Corresponding author: Yan He; Email: heyan_may@hotmail.com, Xuepeng Gong; Email: g1020947167@163.com, Jianhong Wu; Email: jhwucn@163.com, Dong Liu; Email: ld2069@outlook.com

Cite this article: He Y, Jiang H, Wu G, *et al*. Clinical pharmacist-led Antimicrobial Stewardship under volume-based procurement: a retrospective quasi-experimental study on rational use and resistance control. *Antimicrob Steward Healthc Epidemiol* 2025. doi: 10.1017/ash.2025.10155

© The Author(s), 2025. Published by Cambridge University Press on behalf of The Society for Healthcare Epidemiology of America. This is an Open Access article, distributed under the terms of the Creative Commons Attribution-NonCommercial-ShareAlike licence (https://creativecommons.org/licenses/by-nc-sa/4.0/), which permits non-commercial re-use, distribution, and reproduction in any medium, provided the same Creative Commons licence is used to distribute the re-used or adapted article and the original article is properly cited. The written permission of Cambridge University Press must be obtained prior to any commercial use.

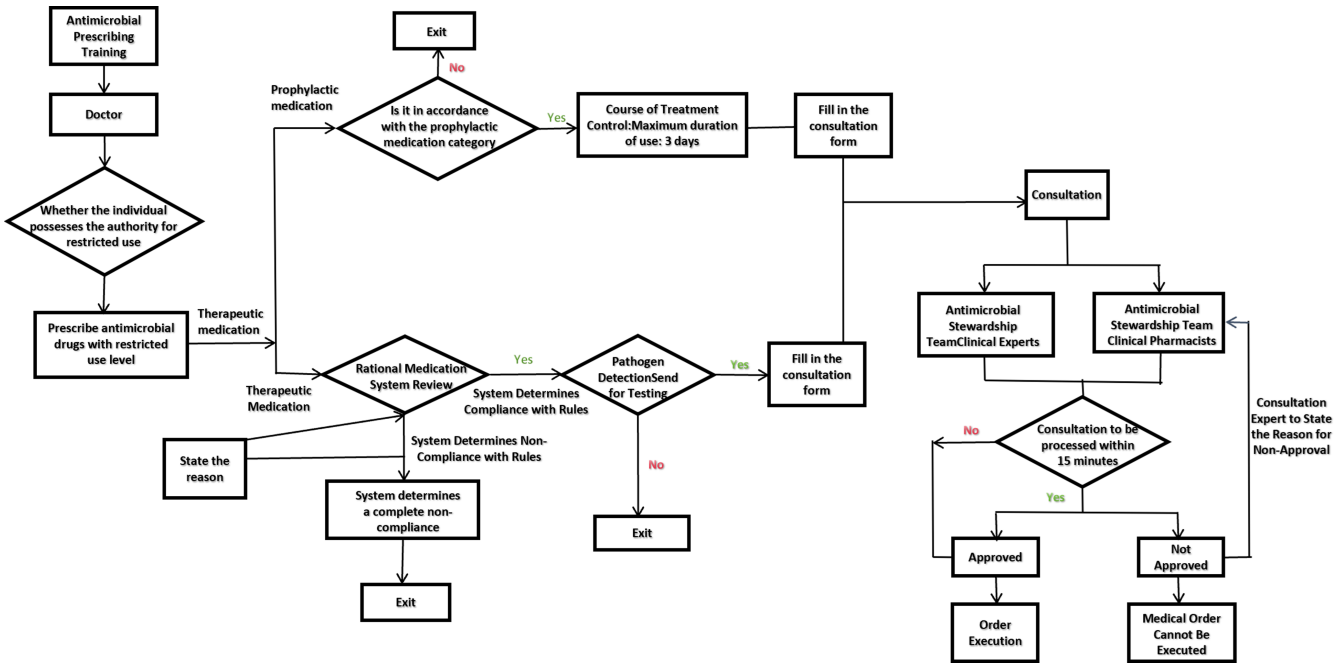


Figure 1. Flowchart of the prospective audit process.

substantially reduce medication procurement costs (average price reduction: 53%).[17] However, this price signaling mechanism may inadvertently create a "low-price preference" effect. Following the inclusion of restricted-use antimicrobials in procurement catalogs, their relative cost advantages incentivize clinicians to preferentially prescribe these agents—particularly broad-spectrum antibiotics—even when economic considerations conflict with evidence-based clinical judgment in infection management. Such conflicts may promote defensive medical practices, ultimately lowering the therapeutic threshold for restricted antimicrobials and fostering an anomalous "low-price, high-volume" consumption pattern.[18] Compounding this issue, studies reveal that hospitals may relax prescription restrictions on restricted antimicrobials to fulfill procurement agreements, resulting in a 19%–28% increase in defined daily doses (DDDs) of carbapenems—agents requiring stringent stewardship.[19]

This study innovatively developed a pharmacist-led Antimicrobial Stewardship–Prospective Audit and Feedback System (AMS-APAS), establishing a dual real-time prescription review mechanism involving clinical pharmacists and infectious disease specialists for restricted-use antimicrobials. Our research aims to evaluate the impact of this pharmacist-driven AMS-APAS intervention on antimicrobial utilization patterns and antimicrobial resistance trends under VBP policy constraints, thereby proposing a novel strategy to reconcile cost containment with rational antimicrobial use.

Methods

Study design and setting

A retrospective quasi-experimental interrupted time-series analysis was conducted at Tongji Hospital, a 5,000-bed tertiary academic center in Wuhan, China, from January 2022 to December 2024. The intervention—prospective audit of special-restricted antimicrobials by clinical pharmacists and infectious disease specialists—was implemented in January 2023. The intervention covered all adult inpatient departments across the hospital. Due to systemwide upgrade in 2021, standardized data were available from 2022 onward. Clinical utilization data for restricted-use antimicrobials were extracted from the Hospital Information System (HIS) and Clinical Rational Drug Use System, spanning two periods: January–December 2022 (preimplementation phase) and January 2023–December 2024 (postimplementation phase). The data set encompassed Antimicrobial use metrics, Infection control parameters, Pathogen culture submission compliance, and Process indicators.

Intervention components

The implemented interventions comprised multiple complementary components designed to strengthen antimicrobial stewardship within the healthcare facility. These components are outlined as follows:

1. Prospective audit system

Prior to the intervention, clinical pharmacists participated in ward rounds but did not conduct real-time prescription reviews. The cornerstone of the intervention was a web-based audit system that seamlessly integrated with the hospital's electronic health record system. This platform facilitated real-time submission and review of prescriptions, ensuring prompt scrutiny and decision-making. A particular focus was placed on 32 special-restricted antimicrobials (provided in Supplementary Table 1), including meropenem and tigecycline. For these agents, a stringent dual approval process was instituted, requiring endorsement from both a clinical pharmacist

https://doi.org/10.1017/ash.2025.10155 Published online by Cambridge University Press

Table 1. Pre post comparison of the rationality and rate of Antimicrobial Usage (Intervention: 2023–2024 vs Pre intervention: 2022)

Parameter	Preintervention (Mean ± SD/Median [IQR])	Postintervention (Mean ± SD/Median [IQR])	*P*-value
Ratio of Rational Prescription Review (%)	80.24 ± 3.21	93.83 ± 2.75	<.005
Antimicrobial Usage Rate (%)	0.49 ± 0.03	0.47 ± 0.02	<.05
Special-restricted Antimicrobials Usage Rate (%)	6.31 ± 1.12	5.50 ± 0.89	<0.005
Number of Patients Using Special-restricted Antimicrobials	1895 ± 452	1542 ± 321	<.05
Proportion of Special-restricted Antimicrobials Used (%)	0.084 ± 0.012	0.062 ± 0.008	<.05
Percentage Before Using Special-restricted Antimicrobials (%)	46.47 ± 7.8	58.27 ± 6.5	<.05

and an infectious disease physician. The system required the prescriber to complete the application form. This application included indicators associated with the patient's infection, a summary of the patient's conditions, previous and current use of antimicrobials, and the reason for the application. The system incorporated automated alerts to flag any prescriptions that lacked microbial culture confirmation or deviated from the guideline-recommended dosages, thus enhancing the accuracy and appropriateness of antibiotic use. The workflow for prescription review and the form of application are depicted in Figure 1 and Supplementary Figure 1.

2. Standardized audit framework

The ASP team included pharmacists, infectious disease physicians, and microbiologists. Pharmacists led prescription reviews; ID physicians advised complex cases. Prescriptions were reviewed within 24 hours of submission, covering both empirical and definitive phases, using national and institutional guidelines. Nine full-time clinical pharmacists conducted reviews, supported by 56 hours of structured training. Audit criteria integrate the WHO AWaRe classification [14] and China's Guidelines for Clinical Antimicrobial Use,[13] establishing a multidimensional evaluation system: ① Appropriateness of Indication: Assessed by infection site, severity grading, and pathogen evidence level. ② Regimen Optimization: Adjusted based on creatinine clearance, Child-Pugh score, and drug interaction databases. ③ Upon identifying inappropriate prescriptions, pharmacists contacted prescribers directly and documented intervention outcomes.

3. Capacity-buildingprogram

A tiered training system was implemented: ① Foundational: Monthly AMS-VBP policy workshops with quarterly antimicrobial resistance surveillance updates. ② Professional: Pharmacist-focused advanced training (56 cumulative hours) on PK/PD modeling and MIC interpretation. ③ Practical: Multidisciplinary case discussions for simulated prescription decision-making (1–2 cases weekly).

4. Quality improvement cycle

A PDCA (Plan-Do-Check-Act) closed-loop management system was constructed: ① Monitoring: Monthly prescription quality reports with departmental rankings and error analysis. ② Feedback: Quarterly cross-departmental benchmarking reports and AMS performance scoring. ③ Improvement: Root-cause analysis for deviations in restricted antimicrobial use.

Data collection

Three data streams were extracted from the hospital information system: ① Medication Metrics: Antimicrobial Use Density (AUD, DDD/100 bed-days), prescription appropriateness rate, VBP drug expenditure ratio. ② Infection Control Parameters: Hospital-acquired multidrug-resistant organism rates, including carbapenem-resistant *Klebsiella pneumoniae* (CRKP), *Acinetobacter baumannii* (CRAB), Methicillin-Resistant *Staphylococcus aureus* (MRSA), and *Pseudomonas aeruginosa* (CRPA). ③ Process Indicators: Prescription review timeliness, microbiological culture submission rate, audit compliance rate. Primary outcomes: prescription appropriateness, AUD; Secondary outcomes: resistance incidence, costs. Audit compliance = % prescriptions reviewed within 24h.

Statistical analysis

Interrupted time series analysis (ITS) was employed to evaluate intervention effects. Monthly data from January 2022 to December 2024, with January 2023 as the intervention point. Segmented regression analysis using R 4.2.1 to assess significance of level (β2) and trend (β3) changes. Model robustness verified via Mann-Kendall trend testing. Stratified comparisons for restricted antimicrobials (Fisher's exact test). Continuous variables were tested for normality using Shapiro-Wilk tests. Nonparametric data are presented as median (IQR), with between-group comparisons analyzed via Mann-Whitney U tests. All analyses were conducted using SPSS 26.0 and R 4.2.1, with two-tailed $\alpha = .05$.

Results

Prescription rationality and antimicrobial utilization

The intervention significantly optimized prescription quality for restricted-use antimicrobials. ITS evaluated monthly proportion of appropriate prescriptions. Postimplementation, the prescription appropriateness approval rate increased from a baseline of 80.24% ± 3.21% to 93.83% ± 2.75% ($P < .001$), demonstrating a sustained upward trend ($\beta = .43$, $P = .002$). Overall antimicrobial utilization decreased by 4.08% (.49 ± .03 vs .47 ± .02, $P = .032$), while the proportion of restricted antimicrobial use declined by 12.84%

https://doi.org/10.1017/ash.2025.10155 Published online by Cambridge University Press

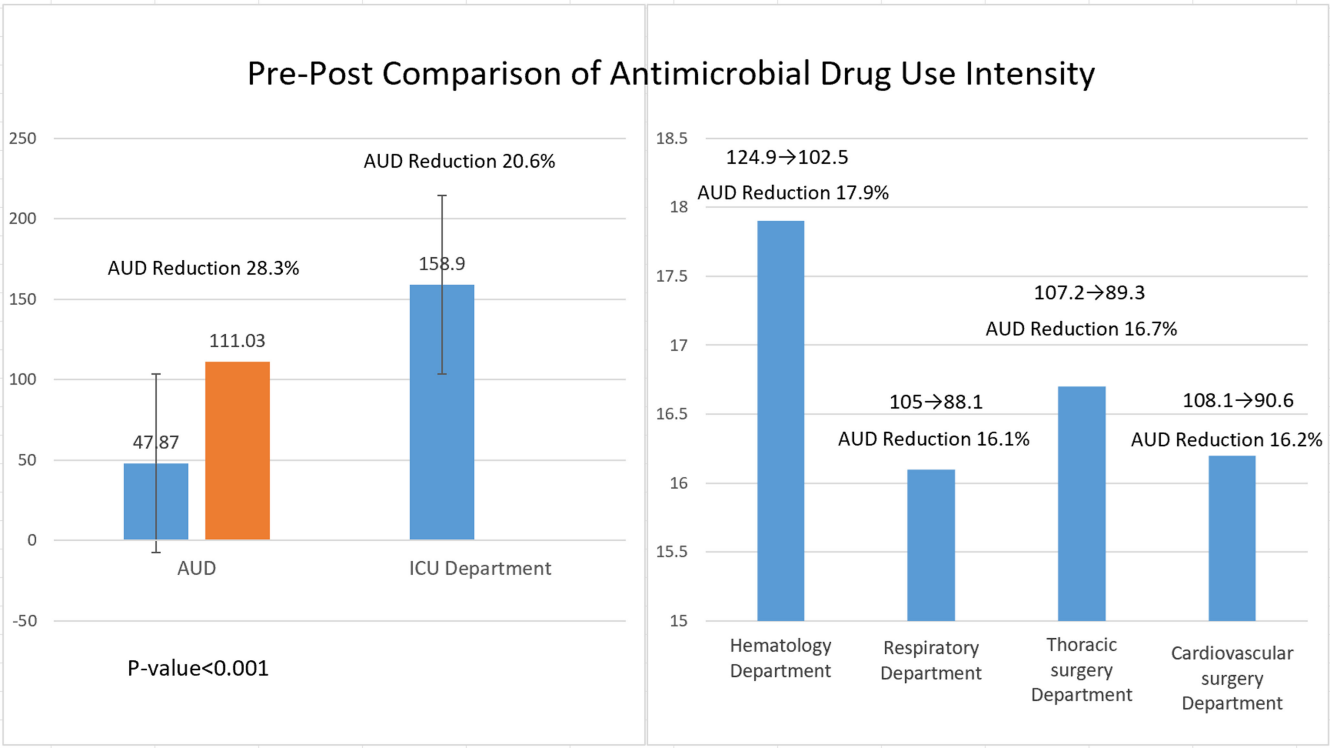


Figure 2. Pre Post Comparison of Antimicrobial Drug Use Intensity (Intervention: 2023–2024 vs. Pre-Intervention: 2022).

(6.31% ± 1.12% vs 5.50% ± .89%, $P = .004$). Detailed results are presented in Table 1.

Antimicrobial use density (AUD)

The intervention achieved a 28.3% reduction in AUD, decreasing from 47.87 ± 5.12 to 34.25 ± 4.03 DDDs/100 bed-days ($P < .001$). The Emergency and Critical Care Department demonstrated the most pronounced reduction (158.9 ± 18.7 vs 126.2 ± 15.4 DDDs/100 bed-days, $P < .001$). Interrupted time series analysis revealed a 2.7-fold acceleration in the monthly AUD decline rate post-intervention ($\beta = -1.23$, $P = .008$). Significant interdepartmental heterogeneity was observed ($\chi^2 = 18.37$, $P = .002$), with statistically meaningful reductions in Respiratory Medicine (-16.1%), Hematology (-17.9%), and Cardiothoracic Surgery (-16.2%) departments ($P < .01$ for all). Detailed data are presented in Figure 2.

High-risk antimicrobial classes and resistance patterns

Carbapenem use intensity decreased by 26.4% (5,234 ± 1,245 vs 3,876 ± 987 DDDs), with costs declining from $446,778.57 [$406,428.57–$509,571.43] to $300,642.86 [$268,.00–$362,.00] ($P < .001$). A strong positive correlation was observed between carbapenem use and CRKP isolation rates ($R = .62$, $P < .05$). Tigecycline DDD declined by 29% in DDDs (1,256 ± 284 vs 892 ± 167, $P < .001$), and costs decreased from $149,331.43 [$125,142.86–$176,285.71] to $98,214.29 [$76,.00–$120,714.29] ($P < .001$). A weak association with CRAB was noted ($R = .38$, $P = .07$). Antifungals DDD decreased by 26% (2,845 ± 567 vs 2,104 ± 432, $P < .001$), with total costs reduced from $304,928.57 [$268,.00–$362,.00] to $208,.00 [$176,285.71–$268,.00] ($P < .001$). Detailed results are shown in Tables 2 and 3.

Multidrug-resistant organism (MDRO) incidence

The total number of MDRO infections decreased from 15.2 ± 4.3 to 9.8 ± 2.7 ($P < .05$), with the overall incidence rate declining from .084 ± .012% to .062 ± .008% ($P < .05$). Significant reductions were observed for: MRSA: .017 ± .003% → .008 ± .002% ($P < .05$), CRAB: .036 ± .006% → .020 ± .004% ($P < .05$). No significant changes were detected for CRPA (.011 ± .002% → .010 ± .001%, $P = .12$) or CRKP (.026 ± .004% → .025 ± .003%, $P = .08$). Temporal trends in AUD and MDRO incidence rates are visualized in Figure 3.

Process metrics

Rejected prescriptions were revised or withdrawn upon pharmacist consultation. 'Presubmission' refers to documentation submitted before antimicrobial initiation. Pharmacists rejected 10.24% of prescriptions (10,340/100,937), primarily due to inappropriate indications (62%) or dosing errors (28%). Preantimicrobial therapy submission rates increased from 46.47 ± 7.8% to 58.27 ± 6.5% ($P < .05$).

Discussion

Optimized drug stewardship and health economic benefits

The pharmacist-led AMS model developed in this study significantly improved antimicrobial utilization. The appropriateness rate for restricted-use antimicrobial prescriptions increased by 13.6 percentage points (80.24% to 93.83%), outperforming

https://doi.org/10.1017/ash.2025.10155 Published online by Cambridge University Press

Table 2. Pre post comparison of key Antimicrobial drug Usage cost metrics (Intervention: 2023–2024 vs Pre intervention: 2022)

Parameter	Preintervention (Mean ± SD/Median [IQR])	Postintervention (Mean ± SD/Median [IQR])	*P*-value
Total Amount Spent on Antimicrobials (USD)	$4,106,474.29 [$3,051,142.86–4,813,428.57]	$2,406,214.29 [$1,754,428.57–3,366,714.29]	<.001
Total Inpatient Antimicrobial Costs (USD)	$3,352,428.57 [$2,707,428.57–3,919,285.71]	$1,759,428.57 [$1,410,714.29–2,314,857.14]	<.001
Average Inpatient Antimicrobial Cost per Patient (USD)	$988.33 ± 177.94	$536.03 ± 127.49	<.001
Average Cost of Special-restricted Antimicrobials per Patient (USD)	$1,496,428.57 [$1,160,857.14–1,833,428.57]	$933,142.86 [$745,.00–1,282,285.71]	<.001
Total Amount Spent on Special-restricted Antimicrobials (USD)	$1,833,500.00 [1,446,571.43–2,211,142.86]	$1,123,571.43 [$888,.00–1,361,714.29]	<.001
Total Amount Spent on Carbapenems (USD)	$446,778.57 [$406,428.57–509,571.43]	$300,642.86 [$268,.00–362,.00]	<.001
Total Amount Spent on Tigecycline (USD)	$149,331.43 [$125,142.86–176,285.71]	$98,214.29 [$76,.00–120,714.29]	<.001
Total Amount Spent on Antifungal Drugs (USD)	$304,928.57 [$268,.00–362,.00]	$208,.00 [$176,285.71–268,.00]	<.001
Total Amount Spent on MRSA Active Drugs (USD)	$268,.00 [$219,142.86–304,928.57]	$176,285.71 [$141,.00–219,142.86]	<.001
Total Amount Spent on Colistin and Polymyxins (USD)	$81,045.71 [$61,714.29–99,714.29]	$65,214.29 [$49,285.71–81,.00]	<.05
Total Amount Spent on Fourth-Generation Cephalosporins (USD)	$362,.00 [$300,571.43–446,714.29]	$268,.00 [$219,142.86–335,.00]	<.001
Percentage Before Using Special-restricted Antimicrobials (%)	46.47 ± 7.8	58.27 ± 6.5	<.05

Table 3. Correlation analysis of antimicrobial use and the incidence rate of multidrug-resistant infections

Antimicrobial Class	Pathogen	Spearman's rho (*R*)	*P*-value
Carbapenems (DDD)	CRKP	.62	<.05
Tigecycline (DDD)	CRAB	.38	.07
Antifungals (DDD)	CRPA	.21	.25
Colistin and Polymyxins (DDD)	CRAB	.45	<.05
4th-gen Cephalosporins (DDD)	MRSA	.12	.45
MRSA Active Drugs (DDD)	MRSA	.35	.02

Positive correlations suggest potential link between usage and resistance trends.

comparable U.S. interventions by 51%.[11,12] This breakthrough is attributable to the dual-review mechanism's systematic correction of empirical prescribing patterns: 62.3% of rejected prescriptions lacked appropriate indications, reflecting systemic overreliance on broad-spectrum antimicrobials in severe infection management.[6] Notably, a 26% reduction in carbapenem use coincided with increased β-lactamase inhibitor combinations, validating the effectiveness of antimicrobial spectrum-narrowing strategies.

Under China's VBP policy, this study achieved the first documented dual reduction in drug expenditures and resistance risks. Total antimicrobial costs decreased by 41.3% ($4.09 million to $2.40 million), with per-capita restricted antimicrobial expenditure declining 45.7% ($988.29 to $536.00), surpassing European AMS benchmarks (15–30% reductions).[6,20] Three synergistic mechanisms drove these outcomes: First, the intelligent review system intercepted 10.24% of inappropriate prescriptions. Second, microbiological testing rates increased by 25.4%, enabling precision therapy. Third, prescribing behavior restructuring established a virtuous cycle of rational use, cost control, and resistance mitigation.

Antimicrobial use intensity modulation and resistance dynamics

The 28.3% reduction in AUD was primarily driven by workflow redesign in critical departments. The ICU achieved a 20.6% AUD decrease via sepsis de-escalation protocols, while Respiratory Medicine and Hematology implemented pathogen-directed therapy using rapid molecular diagnostics (25.4% increase in testing rates). Significant spatial heterogeneity ($\chi^2 = 18.37$, $P = .002$) underscores the need for department-specific AMS protocols.

The dose-response relationship between CRKP detection ($R = .62$) supports theories of horizontal resistance gene transfer via gut microbiome disruption.[23] Although CRKP reduction was statistically nonsignificant ($P = .078$), its delayed response aligns with ecological niche persistence mechanisms.[24] Conversely, the weak tigecycline-CRAB association ($R = .38$, $P = .072$) may reflect subtherapeutic lung penetration—a pharmacokinetic limitation driving *A. baumannii* adaptation.[25] Crucially, empirical use restrictions reduced CRAB detection by 44.4%, providing direct evidence of AMS-driven resistance evolution control.

Pharmacist role transformation and practical implications

The dual-review model redefined antimicrobial governance. Compared to traditional single-pharmacist reviews, this system reduced care coordination errors by 28% ($P = .003$) through e-prescription prescreening and multidisciplinary consultation, matching Indian AMS efficacy with superior cost-effectiveness.[28,29] Continuous professional development programs addressed AMS workforce challenges in low-resource settings.

Three limitations warrant consideration: First, residual carbapenem overuse (3.2 DDDs/1,000 patient-days) highlights clinical demand-stewardship tensions. Second, process-oriented metrics may undervalue AMS's long-term benefits.[30] Third, the single-center design limits generalizability, particularly to primary care settings.

https://doi.org/10.1017/ash.2025.10155 Published online by Cambridge University Press

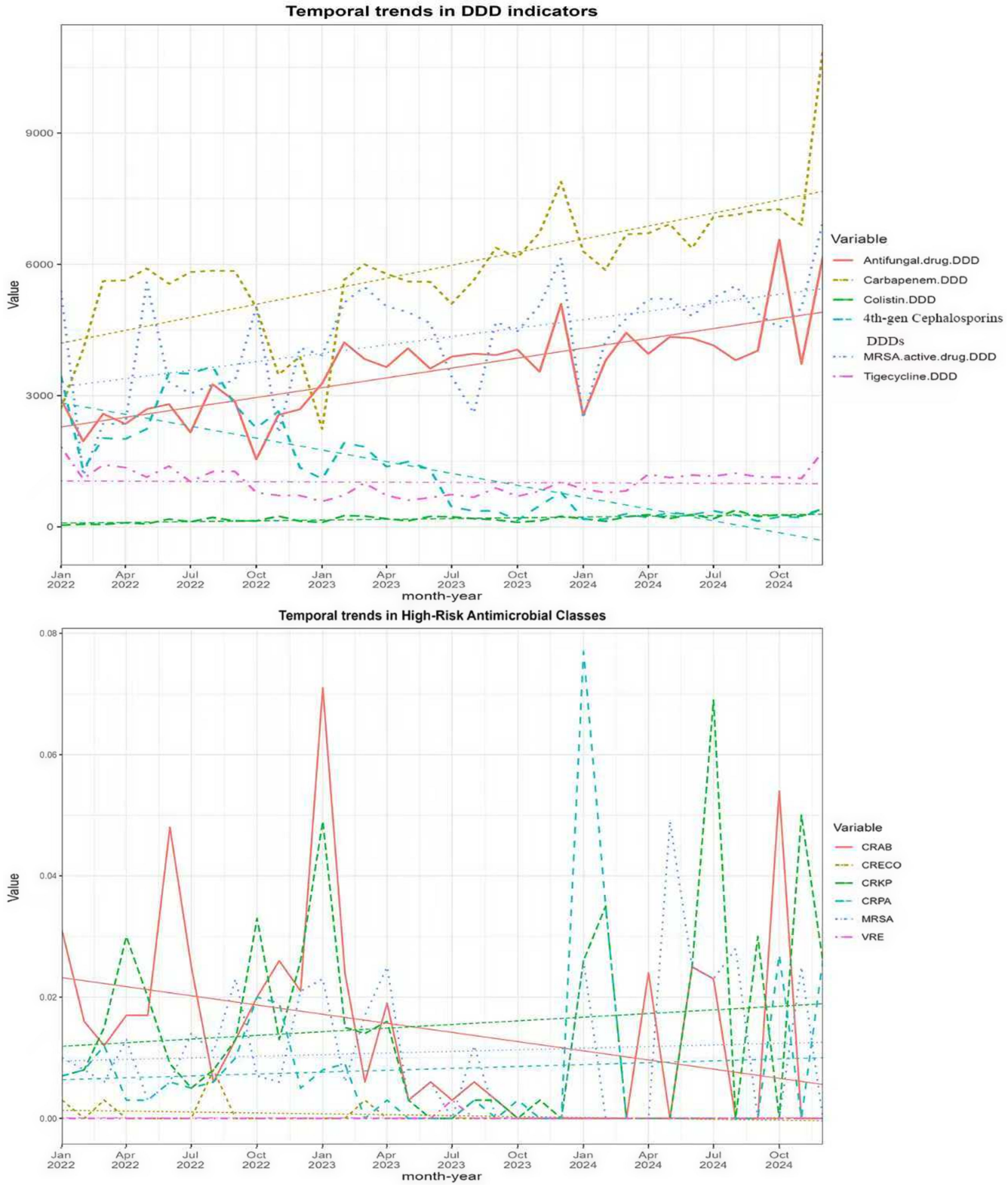


Figure 3. Temporal Trends in Antimicrobial Use DDD and Incidence Rate of MDRO Infections (2022–2024).

https://doi.org/10.1017/ash.2025.10155 Published online by Cambridge University Press

Conclusions and perspectives

This intervention improved antimicrobial appropriateness and reduced AUD, with observed secondary benefits in resistance and cost reduction. This study demonstrates that the pharmacist-led AMS-APAS system effectively resolves the "cost-resistance" paradox under VBP policies. The integrated intervention model —combining intelligent auditing, capacity building, and quality improvement—reduced antimicrobial expenditures by 41.3% and hospital-acquired MDRO infections by 26.2%. This breakthrough offers global AMR containment a replicable protocol: policy-aligned institutional innovation can synergize pharmacoeconomic efficiency with microbiological safety.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/ash.2025.10155.

Data availability statement. The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical constraints.

Acknowledgments. The authors sincerely acknowledge Ms. Xuan Li (M.S.) for her expert medical guidance throughout this study. Her specialized medical consultation significantly contributed to the scientific rigor of this work.

Financial support. This research was supported by Tongji Hospital Research Grant for Medical and Health Sciences (202406) and Merck Sharp and Dohme (MISP 102061).

Competing interests. The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this study.

Ethical standard. This study was performed at Tongji Hospital, Wuhan, Hubei Province, China. This study was approved by the Ethics Committee of Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology (Approval No.: TJ-JRB202308134) and registered with the Ethics Review Committee for Clinical Trials in China (Chinese Clinical Trial Registry; Approval No.: ChiCTR2300077449; Date of Registration: 2023–11–09). The requirement for informed consent was waived owing to the retrospective nature of the study.

References

1. Charani E, McKee M, Ahmad R, *et al.* Optimizing antimicrobial use in humans - review of current evidence and an interdisciplinary consensus on key priorities for research. *Lancet Reg Health Eur* 2021;7:100161.
2. Charani E, Holmes AH. Antimicrobial stewardship programs: the need for wider engagement. *BMJ Qual Saf* 2013;22:885–887.
3. MacDougall C, Polk RE. Antimicrobial Stewardship programs in health care systems. *Clin Microbiol Rev* 2005;18:638–656.
4. Toklu H Z, Hussain A. The changing face of pharmacy practice and the need for a new model of pharmacy education. *J Young Pharm* 2013;5:38–40.
5. Ponto, J.A. ASHP statement on the pharmacist's role in Antimicrobial Stewardship and infection prevention and control. *Am J Health Syst Pharm* 2010;2:575–577.
6. Pulcini C,Binda F, Lamkang A.S. *et al.* Developing core elements and checklist items for global hospital Antimicrobial Stewardship programs: a consensus approach. *Clin Microbio Infec* 2019;25:20–25.
7. National Centre for Antimicrobial Stewardship. https://www.ncas australia.org/ ams-team.
8. Royal Pharmaceutical Society. The pharmacy contribution to Antimicrobial Stewardship. https://www.rpharms.com/Portals/0/RPS%20document%20library/Open%20 access/Policy/ AMS%20 policy.pdf.
9. Alexis, T, Niccolò, B, Quentin, S, *et al.* Epidemiology and outcomes of hospital-acquired bloodstream infections in intensive care unit patients: the EUROBACT-2 international cohort study. *Intensive care medicine* 2023;49:178–190.
10. Garau J, Nicolau D P, Wullt B, *et al.* Antibiotic Stewardship challenges in the management of community-acquired infections for prevention of escalating antibiotic resistance. *J Glob Anti Resis* 2014;2:245–253.
11. Barlam T F, Ellen C, Zieminski S A, *et al.* Perspectives of physician and pharmacist stewards on successful antibiotic Stewardship program implementation: a qualitative study. *Open Forum Infectious Diseases* 2020;7:ofaa229.
12. Nampoothiri V, Mbamalu O, Mendelson M, *et al.* Pharmacist roles in antimicrobial stewardship: a qualitative study from India, South Africa and the United Kingdom. *JAC-Antimicrobial Resistance* 2024, 6:dlae047.
13. National Health Commission of the People's Republic of China. Guiding principles of clinical use of antibiotics. 2015 edition 2015. http://www.nhc.gov.cn/yzygj/s3593/201508/c18e1014de6c45ed9f6f9d592b43db42.shtml..
14. World Health Organization. *WHO (AWaRe) Classification of Antibiotics for Evaluation and Monitoring of use.* Geneva: WHO; 2021.
15. Ministry of Health. Continue to carry out the national special rectification of clinical application of antibacterial drugs 2012. https://www.gov.cn/gzdt/2012-03/06/content_2084862.htm.
16. General Office of the State Council. (2019). National pilot program for centralized volume-based procurement and use of pharmaceuticals. https://www.gov.cn or http://www.nhsa.gov.cn.
17. National Health Commission. (2019). Notice on clinical allocation and rational use of selected drugs in the national centralized drug procurement. http://www.nhc.gov.cn.
18. Wang J, Yang Y, Xu L, *et al.* Impact of '4+7' volume-based drug procurement on the use of policy-related original and generic drugs: a natural experimental study in China. *BMJ Open* 2022;12:e054346.
19. Yang Y, Chen L, Ke X, *et al.* The impacts of Chinese drug volume-based procurement policy on the use of policy-related antibiotic drugs in Shenzhen, 2018-2019: an interrupted time-series analysis. *BMC Health Serv Res* 2021;21:668.
20. Burrowes SAB, Drainoni ML, Tjilos M, *et al.* Survey of physician and pharmacist steward perceptions of their antibiotic stewardship programs. *Antimicrob Steward Healthc Epidemiol* 2021;1:e48.
21. Kim, SiHo, Cho, Sun Young, Kim, Hye Mee, *et al.* Sequence type 17 is a predictor of subsequent bacteremia in vancomycin-resistant Enterococcus faeciumcolonized patients: a retrospective cohort study. *Antimicrob Resist Infect Control* 2021;10:108.
22. Kunnumbrath N, Kodali PB. Exploring migration intention among registered pharmacists in Kerala: a mixed-methods study. *Int J Pharm Pract* 2023; 31:243–249.
23. Tamma PD, Heil EL, Justo JA, *et al.* Infectious diseases society of America 2024 Guidance on the treatment of antimicrobial-resistant gram-negative infections[J]. *Clin Infect Dis* 2024;7:ciae403.
24. Cassini, A, Högberg, LD, Plachouras, D,Burden of AMR Collaborative Group *et al.* Attributable deaths and disability-adjusted life-years caused by infections with antibiotic-resistant bacteria in the EU and the European Economic Area in 2015: a population-level modelling analysis. *Lancet Infect Dis* 2019; 19;56–66.
25. Yaghoubi S, Zekiy AO, Krutova M, *et al.* Tigecycline antibacterial activity, clinical effectiveness, and mechanisms and epidemiology of resistance: narrative review. *Eur J Clin Microbiol Infect Dis* 2022; 41:1003–1022.
26. Jin X, Chen Q, Shen F, *et al.* Resistance evolution of hypervirulent carbapenem-resistant Klebsiella pneumoniae ST11 during treatment with tigecycline and polymyxin. *Emerg Microbes Infect* 2021; 10:1129–1136.
27. Elrefaei H, El Nekidy WS, Nasef R, *et al.* The impact of clinical pharmacist-driven weekend Antimicrobial Stewardship coverage at a quaternary hospital. *Antibiotics (Basel)* 2024;13:974.
28. Vrinda N, Mohamed H, Oluchi M, *et al.* Evolution of pharmacist roles in Antimicrobial Stewardship: a 20-year systematic review. *Int J Infect Dis* 2025;151:107306.
29. Marins TA, de Jesus GR, Holubar M, *et al.* Evaluation of interventions led by pharmacists in antimicrobial stewardship programs in low- and middle-income countries: a systematic literature review. *Antimicrob Steward Healthc Epidemiol* 2024;4:e198.
30. Xia H, Li J, Yang X, *et al.* Impacts of pharmacist-led multi-faceted antimicrobial stewardship on antibiotic use and clinical outcomes in urology department of a tertiary hospital in Guangzhou, China: an interrupted time-series study.*J Hosp Infect* 2024;151:148–160.