Infection and Drug Resistance

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Impact of Pharmacist-Led Anti-Infective Consultations on Therapeutic Outcomes: A Retrospective Cohort Study in a Tertiary Hospital

Chuanwei Xin[1], Bei Zheng[1], Qinqin Zhao[1], Wenjuan Yang[1], Pinpin Feng[1], Yuexing Tu[2]

[1]Department of Pharmacy, Tongde Hospital of Zhejiang Province, Hangzhou, People's Republic of China; [2]Department of Critical Care Medicine, Tongde Hospital of Zhejiang Province, Hangzhou, People's Republic of China

Correspondence: Yuexing Tu, Department of Critical Care Medicine, Tongde Hospital of Zhejiang Province, No. 234 Gucui Road, Xihu District, Hangzhou, Zhejiang Province, 310012, People's Republic of China, Email tuyuexing1988@163.com

Objective: To evaluate the clinical and economic impact of pharmacist-led anti-infective consultations in a Chinese tertiary hospital under diagnosis-related group (DRG) payment reforms.

Methods: This retrospective cohort study analyzed inpatients receiving pharmacist-led anti-infective consultations from Tongde Hospital of Zhejiang Province in 2024. Patients were stratified into adherence and non-adherence groups based on clinicians' implementation of pharmacist recommendations. Outcomes included clinical response rates, adverse drug reactions (ADRs), 14-day mortality, total costs of antimicrobial therapy and total hospitalization costs.

Results: In this study, clinical pharmacists conducted 498 anti-infective therapy consultations for 313 patients, with 82.13% (409/498) of their recommendations being accepted by clinicians. The results demonstrated that adherence to clinical pharmacist recommendations significantly enhanced the clinical response rate (81.99% vs 38.46%, $p < 0.05$), decreased the incidence of adverse drug reactions (4.21% vs 13.46%, $p< 0.05$), and reduced 14-day mortality (5.75% vs 17.31%, $p< 0.05$). Furthermore, adherence led to a 69% reduction in the average cost of antimicrobial therapy ($1830.79 vs $5983.14, $p< 0.05$) and a 58% decrease in the average total cost of hospitalization ($15,306.17 vs $36,799.11, $p< 0.05$).

Conclusion: Pharmacist-led anti-infective consultations demonstrate efficacy in enhancing infection treatment outcomes and curbing antimicrobial expenditures, providing actionable evidence for scaling antimicrobial stewardship programs in one DRG-based hospital in China.

Keywords: pharmacist-led consultations, anti-infective, therapeutic outcomes

Introduction

As the global burden of antimicrobial resistance (AMR) continues to rise, it not only complicates the treatment of common infections but also results in prolonged illness, higher mortality rates, and escalating healthcare costs.[1,2] Consequently, there is an urgent need for innovative strategies to manage antimicrobial resistance effectively. Pharmacist-led antimicrobial stewardship programs (ASPs) have demonstrated substantial clinical benefits in critically ill neonates, with a 23% reduction in the overall antibiotic use rate (95% CI: 0.69–0.871) and the overall duration of antibiotic therapy significantly reduced by 15% (95% CI: 0.78–0.91, $p < 0.001$).[3]

In China, healthcare reforms such as the Diagnosis-Related Groups/Diagnosis-Intervention Packet (DRG/DIP) payment system are promoting a shift toward patient-centered pharmaceutical care.[4] Concurrently, the 2022 National Action Plan to Control Antibiotic Resistance underscores the urgency of addressing AMR in the country. Epidemiologically, the prevalence of ESBLs in *Escherichia coli* is as high as approximately 50%, and *Acinetobacter baumannii-calcoaceticus* complex (ABC) has a high antimicrobial resistance profile, with a carbapenem resistance rate of

Received: 15 April 2025
Accepted: 1 July 2025
Published: 28 July 2025

approximately 66%.[5] However, due to China's large population and regional disparities in development, the advancement of clinical pharmacy services remains insufficient and uneven. For instance, many hospitals lack standardized procedures and implementation guidelines for pharmaceutical consultations. Notably, it is challenging for emergency department physicians to adhere to the etiological examination protocol due to the rapid patient turnover, resulting in the overuse of broad-spectrum antibiotics.[6] While many physicians opt for empirical treatment, pharmacists tend to support a guidance-driven de-escalation strategy. However, the absence of effective communication channels often leads to conflicting clinical decisions.[7] This gap underscores the systemic challenge associated with the implementation of the "multi-disciplinary collaboration model" in the Guiding Principles for the Clinical Use of Antibiotics in China.

This retrospective study assessed data from pharmacists involved in anti-infective consultations at a 2100-bed tertiary general hospital. It analyzed the characteristics of consultation cases and evaluated the impact of pharmacist-led anti-infective pharmaceutical consultations on patient clinical outcomes and antimicrobial treatment costs, providing valuable insights to promote the safe and rational use of anti-infective drugs.

Methods

Study Design, Setting

This study was conducted at Tongde Hospital of Zhejiang Province, a public tertiary general hospital located in Hangzhou, the capital city of Zhejiang Province in southeast China. As a government-funded institution, it plays a pivotal role in providing accessible and affordable medical services to the public. The hospital is equipped with 2100 beds and serves around 50,000 discharged patients annually. In 2024, the hospital maintained an average bed occupancy rate of approximately 93.64%. The antimicrobial stewardship team comprises 11 board-certified clinical pharmacists who completed the 12-month Standardized Training Program of Clinical Pharmacists accredited by the Chinese Pharmaceutical Association. Two infection disease-specialized pharmacists conducted daily multidisciplinary ward rounds, implementing precision interventions including pharmacogenomics-guided dosing, therapeutic drug monitoring (TDM), and resistance gene profiling for carbapenemase–producing organisms. At Tongde Hospital of Zhejiang Province, liquid chromatography–tandem mass spectrometry (LC-MS/MS) is used to monitor plasma concentrations of 22 commonly used antimicrobial agents, with vancomycin and voriconazole serving as key examples. For vancomycin, clinical pharmacists adhere to AUC-guided TDM principles to perform therapeutic monitoring,[8] provide individualized dosing recommendations, and mitigate renal toxicity. For voriconazole, maintaining trough plasma concentrations within the range of 1–5.5μg/mL is recommended to optimize antifungal efficacy while minimizing hepatotoxicity, in line with established clinical guidelines.[9]

We extracted all anti-infective pharmaceutical consultation records between January 1 and December 31, 2024 from the Hospital Information System (HIS), with patient-level clinical data retrieved via unique anonymized identifiers from the Electronic Medical Record (EMR). Patients were included if they: (1) had laboratory-confirmed bacterial/fungal infections requiring systemic antimicrobial therapy; (2) underwent pharmacist-led antimicrobial regimen adjustments (dose optimization, drug class switching, or combination therapy) based on microbiological evidence or TDM; and (3) had complete documentation of clinical outcomes. Records were excluded with incomplete critical data (such as the lack of patient clinical symptom changes, laboratory tests and patient outcome description).

Outcomes and Measurement

This study systematically gathered data on the demographic characteristics of patients (age, gender, underlying diseases), distribution of infectious lesions, etiological culture results, levels of inflammatory markers (C-reactive protein, procalcitonin, white blood cell count), trends in temperature changes, and imaging findings (eg, chest CT). Records were maintained for the purpose of pharmaceutical consultations, details of adjustments to the anti-infective treatment plan before and after consultation (including drug selection, dosage, and duration), occurrence of adverse drug reactions, and treatment costs (including antimicrobial expenses and total hospitalization costs). Patients were categorized into the pharmacist recommendation adherence group and the non-adherence group based on whether they followed the consultation recommendations. Anti-infective treatment effects (clinical response rate, 14-day mortality), incidence of

adverse reactions, and differences in treatment costs between the two groups were compared and analyzed. The primary outcome measure was the clinical response rate, defined as the disappearance of infection-related signs or significant improvement in biochemical indicators (normalization of body temperature, reduction in inflammatory markers ≥50%, and imaging absorption ≥30%) at the end of treatment.[10] Secondary outcomes included the 14-day mortality, the incidence of adverse reactions during antimicrobial therapy and direct medical costs (calculated based on actual expenditures recorded in the hospital financial system).

Pharmacy Consultation Workflow

Upon receiving a clinical pharmacist consultation request from a physician, the consulting pharmacist first clarifies the consultation objectives by reviewing the request form. The pharmacist then systematically evaluates the patient's medical records, prioritizing medication-related clinical data. Key data include patient demographics (age, gender, height, weight, and lifestyle habits), clinical information encompassing current and past medical history, family history, allergies, comorbidities, complications, and disease progression, as well as medication profile details such as drug history, therapeutic efficacy, adverse drug reactions, and adherence. Subsequently, the pharmacist conducts a structured patient or caregiver interview to obtain direct insights aligned with the consultation objectives. Key interview themes include disease progression, current pharmacotherapy, treatment responses, and adherence barriers. The pharmacist then collaborates with the attending medical team (physicians and nurses) to discuss the patient's treatment plan, implementation status, and unresolved medication-related issues, enabling a comprehensive assessment of clinical and therapeutic status. Finally, the pharmacist synthesizes evidence-based recommendations addressing therapeutic safety, efficacy, cost-effectiveness, appropriateness, accessibility, and adherence, while integrating patient-specific clinical characteristics and evidence-based guidelines. These recommendations are documented as a consultative reference for therapeutic decision-making, with final treatment plans determined by the prescribing physician. All consultations must be completed within 24 hours, and the pharmacist's documentation is formally integrated into the patient's institutional medical records.

Statistical methods

All statistical analyses were conducted using SPSS statistical software (version 25.0). All data are expressed as number and percentage, The Mann–Whitney *U*-test, Chi-square test and Fisher's exact test were employed for intergroup comparisons, with a significance level set at $p < 0.05$.

Results

The Number of Pharmacist-Led Anti-Infective Consultation

In 2024, clinical pharmacists conducted 498 anti-infective therapy consultations for 313 patients (184 males, 58.8%; 129 females, 41.2%), with ages spanning from 1 to 101 years (mean 67.9 ±20.5). The detailed flow chart of Pharmacist-Led consultations screening is shown in Figure 1. Pulmonary infections predominated (61.65%), followed by Bloodstream infections (19.08%) and Urinary tract infections (14.26%), collectively accounting for 95% of cases. Less common presentations included abdominal (2.41%) and skin/soft tissue infections (2.01%), as it was shown in Table 1. Pathogenic microorganisms were identified in patients by culture-based methods and advanced molecular diagnostic techniques, such as next-generation sequencing (NGS) and polymerase chain reaction (PCR). A total of 293 pathogenic bacteria were detected, with Gram-negative bacteria being predominant, primarily including *Klebsiella pneumoniae, Pseudomonas aeruginosa*, and *Escherichia coli*. Additionally, *Candida albicans* and *Staphylococcus aureus* were also identified, as detailed in Table 2. Among 66 clinically detected cases of *Klebsiella pneumoniae* infection, 37 cases (56.06%) exhibited carbapenem resistance. Concurrently, among 19 detected cases of *Acinetobacter baumannii* infection, 11 cases (57.89%) were identified as carbapenem-resistant. This microbiological profile underscores the critical role of rapid diagnostic technologies in guiding antimicrobial stewardship interventions.

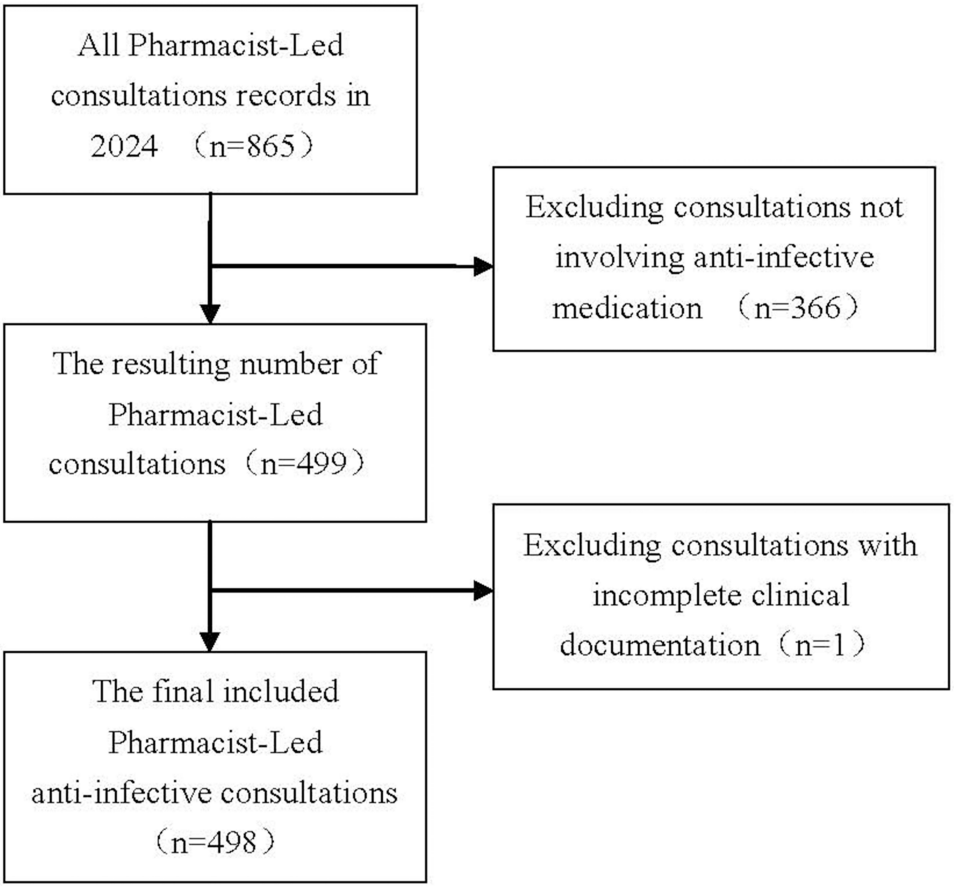

Figure 1 The flow chart of Pharmacist-Led consultations screening.

The Purpose of Applying for Pharmacist-Led Anti-Infective Consultations

As shown in Figure 2, which outlines the purpose of applying for pharmaceutical consultation, Therapeutic adjustment for suboptimal efficacy (47.19%) was the most common reason, followed by Pathogen-Directed Antimicrobial Initiation (35.94%). Together, these two categories accounted for 83.13% of all pharmacist consultations, underscoring the critical role of pharmacists in optimizing empirical therapy. Additionally, the need for pharmacokinetics/pharmacodynamics (PK/

Table 1 Anatomic Distribution of Infection Sites Among Patients Receiving Pharmacist-Led Anti-Infective Consultations

Anatomic Distribution of Infection Sites	Number (n)	Percentage (%)
Pulmonary Infections	307	61.65
Bloodstream Infections	95	19.08
Urinary System Infections	71	14.26
Intra-abdominal Infections	12	2.41
Skin and Soft Tissue Infections (SSTI)	10	2.01
Oral Infections	2	0.40
Central Nervous System Infections	1	0.20
Total	498	100

Table 2 Distribution of Pathogens in Patients Receiving Pharmacist-Led Consultations

Types of Pathogenic Bacteria	Bacterial Latin Scientific Names	Number (n)	Percentage (%)
Gram-negative bacteria	*Klebsiella pneumoniae*	66	22.53
	Pseudomonas aeruginosa	38	12.97
	Escherichia coli	30	10.24
	Acinetobacter baumannii	19	6.48
	Stenotrophomonas maltophilia	18	6.14
	Enterobacter cloacae	12	4.10
	Proteus mirabilis	7	2.39
	Serratia marcescens	3	1.02
Gram-positive bacteria	*Staphylococcus aureus*	28	9.56
	Enterococcus faecium	12	4.10
	Staphylococcus haemolyticus	2	0.68
	Staphylococcus hominis	1	0.34
Fungi	*Candida albicans*	29	9.90
	Aspergillus spp.	17	5.80
	Mucorales	9	3.07
	Candida tropicalis	2	0.68

PD) expertise in complex patient populations was highlighted by the optimization of dosing regimens (9.84%) and determination of treatment duration (3.41%). Meanwhile, Adverse Drug Reaction (ADR) Assessment and Intervention and Drug-Drug Interaction (DDI) Identification accounted for 2.21% and 1.41%, respectively.

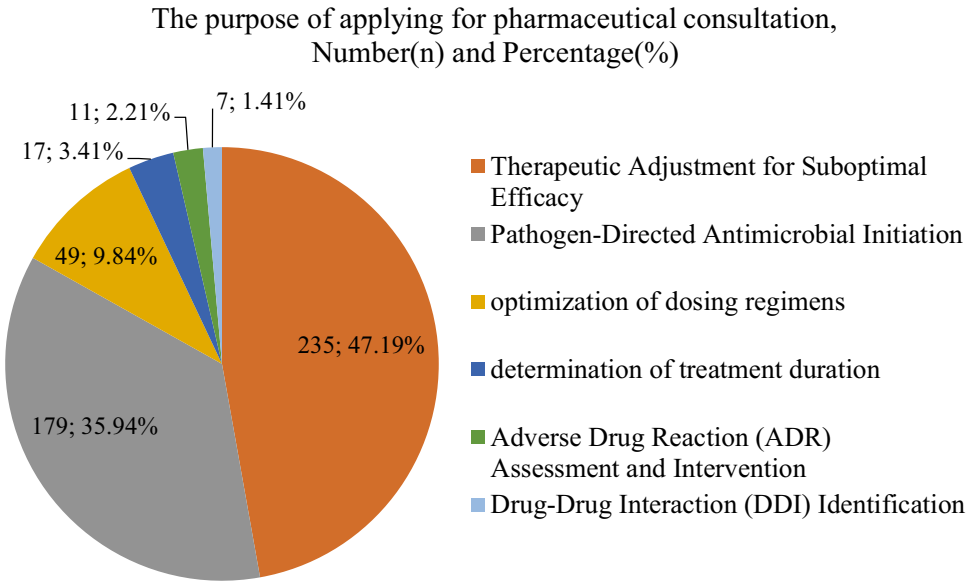

Figure 2 Distribution of the purpose of applying for pharmacist-led consultations.

https://doi.org/10.2147/IDR.S534678

Distribution of Requesting Pharmacist-Led Anti-Infection Consultations and Consultation Acceptance Rate

Among the 498 consultations for anti-infection pharmacy services, requests were made by 17 distinct clinical departments. The department of hematology had the highest number of applications (143, 28.71%), followed by the department of rehabilitation (73, 14.66%) and the Department of Respiratory (57, 11.45%). Overall, 82.13% (409/498) of consultations were accepted, with the acceptance rates ranging from 58.33% in the ICU to 100% in Cardiology, Gastroenterology, and Endocrinology. Non-critical care specialties, including rehabilitation (90.41%), respiratory (89.47%), and geriatrics (89.09%), exhibited consistently high adherence (>85%), whereas the ICU demonstrated the lowest adoption rate (58.33%), as it was shown in Table 3.

Clinical and Economic Outcomes of Pharmacist-Led Anti-Infection Consultations

To evaluate the clinical and economic impact of pharmacist-led anti-infection consultations, we stratified patients into two cohorts based on clinician implementation of consultation recommendations: the pharmacist recommendation adherence group (n = 261) and the non-adherence group (n = 52). As shown in Table 4, the adherence group demonstrated superior clinical efficacy, with an 81.99% clinical response rate compared to 38.46% in the non-adherence group ($p< 0.05$). Pharmacist-guided interventions significantly reduced adverse drug reactions by 69%

Table 3 Distribution of Requesting Clinical Departments and Acceptance Rate of Pharmacist Recommendations

Department	Number of Consultations (n)	Percentage (%)	The Number of Accepted Consultations (n)	Acceptance Rate (%)
Hematology	143	28.71	107	74.83
Rehabilitation	73	14.66	66	90.41
Respiratory	57	11.45	51	89.47
Geriatrics	55	11.04	49	89.09
Oncology	38	7.63	30	78.95
Nephrology	30	6.02	23	76.67
Cadre Health Care	29	5.82	24	82.76
Neurosurgery	15	3.01	12	80.00
Neurology	13	2.61	11	84.62
Intensive Care Unit	12	2.41	7	58.33
General Surgery	13	2.61	11	84.62
Cardiology	5	1.00	5	100.00
Gastroenterology	4	0.80	4	100.00
Infectious Diseases	5	1.00	4	80.00
Pediatrics	3	0.60	2	66.67
Endocrinology	2	0.40	2	100.00
Psychiatry	1	0.20	1	100.00
Total	498	100	409	82.13

Table 4 Clinical and Economic Outcomes of Pharmacist-Led Anti-Infection Consultations

Characteristic	The Pharmacist Recommendation Adherence Group (n=261)	The Non-Adherence Group (n=52)	*P-value*
Clinical response rate (%)	81.99	38.46	p < 0.05
The incidence of adverse drug reactions (%)	4.21	13.46	p < 0.05
14-day mortality (%)	5.75	17.31	p < 0.05
The average cost of antimicrobial therapy ($)	1830.79	5983.14	p < 0.05
The average total cost of hospitalization ($)	15,306.17	36,799.11	p < 0.05

Note: Italicized values in this column indicate P-values.

(4.21% vs 13.46%, p< 0.05) and lowered 14-day mortality by 67% (5.75% vs 17.31%; p< 0.05). Economically, the average cost of antimicrobial therapy was reduced by 69% ($1830.79vs. $5, 983.14, p< 0.05), while the average total cost of hospitalization decreased by 58% ($15,306.17 vs. $36,799.11, p< 0.05) in the adherence cohort. These findings robustly validate the clinical and economic value of integrating pharmacists into antimicrobial stewardship programs.

Discussion

Since initiating clinical pharmacy services in 2007 and establishing a dedicated antimicrobial stewardship consultation system from 2020 in our hospital, a total of 498 anti-infection pharmacy consultations for 313 people were completed in 2024, covering 17 clinical departments. This evolution reflects both the escalating complexity of anti-infective therapeutic demands and the growing recognition of clinical pharmacists' expertise by physicians.

Pharmacist-led anti-infective consultations were primarily driven by therapeutic regimen optimization, with 47.19% for therapeutic adjustment for suboptimal efficacy and 35.94% for Pathogen-Directed antimicrobial initiation. The high frequency of therapeutic adjustments reflects challenges in empirical therapy selection, particularly in settings with rising carbapenem-resistant *Enterobacteriaceae* (CRE) and extended-spectrum β-lactamase (ESBL)-producing pathogens.[11] Pharmacists' roles in de-escalating broad-spectrum regimens or escalating therapy for culture-negative bloodstream infections are consistent with studies demonstrating reduced mortality and hospital stays when stewardship programs are implemented. The 9.84% consultations for dose optimization highlight the necessity of PK/PD expertise, especially in critically ill or renally impaired patients. For instance, vancomycin requires individualized dosing to avoid toxicity.[12] On the other hand, there were also a certain proportion of consultations on ADR and DDI. According to a report from Hughes JE et al,[13] DDI exposure has been associated with increased adverse drug events and decreased health-related quality of life. Implementing CYP_2C_{19}-guided voriconazole dosing,[14] as demonstrated in hematopoietic stem cell transplant cohorts, could preemptively address metabolic interactions exacerbated by polypharmacy.

The elevated consultation frequency observed in hematology (28.71%), rehabilitation medicine (14.66%), and respiratory departments (11.45%) correlated strongly with patient complexity: hematology consultations primarily addressed chemotherapy-induced febrile neutropenia necessitating tailored empirical coverage for multidrug-resistant (MDR) pathogens, while rehabilitation medicine cases predominantly involved polymedicated elderly patients with multimorbidity, presenting high risks of drug-drug interactions and atypical infection manifestations. In the department of respiratory, frequent invasive interventions such as prolonged mechanical ventilation (≥48 hours) elevated susceptibility to ventilator-associated pneumonia (VAP) and biofilm-related infections.[15] These patterns align with evidence demonstrating that pharmacist-led antimicrobial stewardship reduces inappropriate antibiotic use in high-risk populations, underscoring the critical role of interdisciplinary collaboration in managing complex infections.[3]

The microbiological analysis of infections requiring pharmacist consultation revealed a predominance of Gram-negative bacteria, with *Klebsiella pneumoniae* (22.53%), *Pseudomonas aeruginosa* (12.97%), and *Escherichia coli* (10.24%) as the most frequent isolates. These findings align with global trends of escalating Gram-negative infections in hospitalized populations, particularly in critical care settings where MDR pathogens such as *carbapenem-resistant*

K. pneumoniae (CRKP) and *Acinetobacter baumannii* pose significant therapeutic challenges.[16,17] Non-fermentative Gram-negative bacteria, including *A. baumannii* (6.48%) and *Stenotrophomonas maltophilia* (6.14%), further emphasize the need for enhanced infection control measures to mitigate colonization risks associated with medical devices. Fungal infections accounted for 19.45% of cases, predominantly *Candida albicans* (9.90%) and *Aspergillus spp*. (5.80%), reflecting the vulnerability of immunocompromised populations to invasive fungal diseases. Furthermore, *Mucorales* (3.07%) infections underscore the necessity for antifungal stewardship in patients receiving immunosuppressive therapies, particularly those with hematological malignancies or prolonged corticosteroid use.[18] These findings necessitate targeted interventions, including rapid molecular diagnostics and antimicrobial stewardship programs to optimize empirical therapy and reduce resistance propagation.

The overall acceptance rate of 82.13% suggesting institutional success in fostering pharmacist-clinician collaboration. The observed disparity in acceptance rate between departments likely reflects differences in clinical urgency, patient complexity, and interdisciplinary workflows. The high adherence in rehabilitation (90.41%) and geriatrics (89.09%) aligns with studies demonstrating pharmacist effectiveness in optimizing long-term medication regimens for chronic conditions, where therapeutic adjustments are less time-sensitive and allow for collaborative decision-making.[19] Conversely, the ICU's low acceptance rate (58.33%) may stem from the dynamic nature of critical care, where rapid clinical deterioration often necessitates immediate empirical interventions, leaving limited time for pharmacist input. This aligns with prior research showing that ICU physicians may prioritize bedside experience over external recommendations during emergent scenarios.[20] To address this, optimal ICU outcomes likely require collaboration between two key stakeholders: pharmacists and clinicians. For example, pharmacists' real-time expertise can refine empirical regimens while incorporating clinicians' contextual insights. This collaborative approach emphasizes integrating evidence-based guidelines with patient-specific dynamics to facilitate personalized antimicrobial therapy management.

Based on the comparative analysis of clinical and economic outcomes between the pharmacist recommendation adherence group and the non-adherence group, the data robustly demonstrate that adherence to pharmacist-led antimicrobial stewardship interventions significantly improved clinical efficacy and reduced healthcare costs. Pharmacist-guided optimization resulted in a higher clinical response rate (81.99% vs 38.46%), a 69% reduction in adverse drug reactions (4.21% vs 13.46%), and a 67% lower 14-day mortality (5.75% vs 17.31%). Economically, the average cost of antimicrobial therapy decreased by 69% ($1830.79vs. $5983.14; $p< 0.05$), while the average total cost of hospitalization was 58% lower ($15,306.17 vs. $36,799.11; $p< 0.05$) in the adherence group, validating the clinical-economic value of Pharmacist-Led Anti-infective Consultations. These findings are consistent with prior studies demonstrating that pharmacist-led aminoglycoside stewardship resulted in a 56% cost reduction.[21] Additionally, the clinical pharmacist-supplemented medication reconciliation service for patients with chronic kidney disease (CKD) was estimated to have a cost of $714 per patient.[22]

This study has several limitations. First, its single-center retrospective design may limit generalizability, as pharmacist consultation efficacy can vary across institutions due to differences in service models (eg, proactive vs reactive consultations) and antimicrobial stewardship protocols. Second, the study did not formally match the intervention and control groups for baseline clinical characteristics, which may introduce confounding variables that impact the results. Third, due to the relatively limited sample size, the statistical power of subgroup analysis is reduced, so the long-term effects of pharmacist consultation on patients need to be further studied. Future prospective multicenters are needed to validate these findings in different hospital, particularly in low-and middle-income countries where the burden of antibiotic resistance is higher.

Conclusion

In conclusion, this retrospective study demonstrated that adherence to clinical pharmacist recommendations significantly improved the clinical response rate (81.99% vs 38.46%), reduced the incidence of adverse drug reactions (4.21% vs 13.46%), and decreased healthcare expenditures (with a 69% reduction in the average cost of antimicrobial therapy and a 58% decrease in the average total cost of hospitalization), highlighting the critical value of multidisciplinary

collaboration in infectious disease management. Prospective studies are warranted to further validate the specific contributions of pharmacist-led consultations strategies.

Ethics Approval and Consent to Participate

Ethical approval was obtained from the Tongde Hospital of Zhejiang Province (Approval No: 2025-161-JY), with waived informed consent due to the retrospective nature of the study. All patient data involved in the research were handled with strict confidentiality to protect participants' privacy. The study was conducted in compliance with the principles of the Declaration of Helsinki.

Acknowledgments

We would like to thank the patient for participating in this study.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Wernli D, Søgaard Jørgensen P, Parmley EJ, et al. Scope and applicability of social-ecological resilience to antimicrobial resistance. *Lancet Planet Health*. 2023;7(7):e630–e637. PMID: 37438004. doi:10.1016/S2542-5196(23)00128-6
2. Aggarwal R, Mahajan P, Pandiya S, et al. Antibiotic resistance: a global crisis, problems and solutions. *Crit Rev Microbiol*. 2024;50(5):896–921. PMID: 38381581. doi:10.1080/1040841X.2024.2313024
3. Lee SY, An SH. Impact of pharmacist intervention in antibiotic stewardship programmes for critically ill neonates: a systematic review and meta-analysis. *J Clin Pharm Ther*. 2022;47(4):430–444. PMID: 34716722. doi:10.1111/jcpt.13553
4. Gao S, Wang X, Lu Y, et al. Current scenario and challenges of clinical pharmacists to implement pharmaceutical care in DRG/DIP payment hospitals in China: a qualitative interview study. *Front Public Health*. 2024;12:1339504. PMID: 38444434; PMCID: PMC10912177. doi:10.3389/fpubh.2024.1339504
5. Qin X, Ding L, Hao M, Li P, Hu F, Wang M. Antimicrobial resistance of clinical bacterial isolates in China: current status and trends. *JAC Antimicrob Resist*. 2024;6(2):dlae052. PMID: 38549710; PMCID: PMC10977948. doi:10.1093/jacamr/dlae052
6. Kooda K, Canterbury E, Bellolio F. Impact of pharmacist-led antimicrobial stewardship on appropriate antibiotic prescribing in the emergency department: a systematic review and meta-analysis. *Ann Emerg Med*. 2022;79(4):374–387. PMID: 35039180. doi:10.1016/j.annemergmed.2021.11.031
7. Jarab AS, Al-Alawneh TO, Alshogran OY, et al. Knowledge and attitude of healthcare prescribers and pharmacists toward antimicrobial stewardship program and the barriers for its implementation. *Antimicrob Resist Infect Control*. 2024;13(1):35. PMID: 38566242; PMCID: PMC10985862. doi:10.1186/s13756-024-01382-9
8. Bland CM, Crosby CM, Orvin DL, Smith SE, Jones BM. Transitioning from guideline approval to practical implementation of AUC-based monitoring of vancomycin. *Am J Health Syst Pharm*. 2021;78(14):1270–1272. PMID: 33772267. doi:10.1093/ajhp/zxab132
9. Kably B, Launay M, Derobertmasure A, Lefeuvre S, Dannaoui E, Billaud EM. Antifungal Drugs TDM: trends and Update. *Ther Drug Monit*. 2022;44(1):166–197. PMID: 34923544. doi:10.1097/FTD.0000000000000952
10. Pirracchio R, Venkatesh B, Legrand M. Low-dose corticosteroids for critically III adults with severe pulmonary infections: a review. *JAMA*. 2024;332(4):318–328. PMID: 38865154. doi:10.1001/jama.2024.6096
11. Karlowsky JA, Lob SH, DeRyke CA, et al. Prevalence of ESBL non-CRE Escherichia coli and Klebsiella pneumoniae among clinical isolates collected by the SMART global surveillance programme from 2015 to 2019. *Int J Antimicrob Agents*. 2022;59(3):106535. PMID: 35091052. doi:10.1016/j.ijantimicag.2022.106535
12. Al-Maqbali JS, Shukri ZA, Sabahi NA, Al-Riyami I, Al Alawi AM. Vancomycin therapeutic drug monitoring (TDM) and its association with clinical outcomes: a retrospective cohort. *J Infect Public Health*. 2022;15(5):589–593. PMID: 35500543. doi:10.1016/j.jiph.2022.04.007
13. Hughes JE, Bennett KE, Cahir C. Drug-drug interactions and their association with adverse health outcomes in the older community-dwelling population: a prospective cohort study. *Clin Drug Investig*. 2024;44(6):439–453. PMID: 38878216; PMCID: PMC11196341. doi:10.1007/s40261-024-01369-9
14. Patel JN, Robinson M, Morris SA, et al. Pharmacogenetic and clinical predictors of voriconazole concentration in hematopoietic stem cell transplant recipients receiving CYP2C19-guided dosing. *Pharmacogenomics J*. 2023;23(6):201–209. PMID: 37925536. doi:10.1038/s41397-023-00320-z
15. Pokhrel N, Neupane A, Thapa N, Yadav RK, Hamal PK, Malla P. Respiratory morbidity and mortality of traumatic cervical spinal injury. *J Nepal Health Res Counc*. 2024;21(4):680–683. PMID: 38616602. doi:10.33314/jnhrc.v21i4.5068
16. Zhou X, Wagh K, Lv G, Sharma D, Lei W. Genome drafting of nosocomial infection CRE Klebsiella pneumonia confirming resistance to colistin and eravacycline, carrying blaNDM-1, mcr-1, and blaKPC-2, in neonatology from November to December 2023. *Front Cell Infect Microbiol*. 2025;14:1528017. PMID: 39931631; PMCID: PMC11807969. doi:10.3389/fcimb.2024.1528017
17. Chen TA, Chuang YT, Lin CH. A decade-long review of the virulence, resistance, and epidemiological risks of Klebsiella pneumonia in ICUs. *Microorganisms*. 2024;12(12):2548. PMID: 39770751; PMCID: PMC11678397. doi:10.3390/microorganisms12122548
18. Boutin CA, Durocher F, Beauchemin S, Ziegler D, Abou Chakra CN, Dufresne SF. Breakthrough invasive fungal infections in patients with high-risk hematological disorders receiving voriconazole and posaconazole prophylaxis: a systematic review. *Clin Infect Dis*. 2024;79(1):151–160. PMID: 38752732; PMCID: PMC11259221. doi:10.1093/cid/ciae203

19. Conroy GM, Marut DM, Gomes JA, Street S, Idoine J, Ahrens C. Pharmacist impact in a post neuro intensive care virtual clinic (PREVAIL). *J Pharm Pract*. 2024:8971900241308624. PMID: 39672602. doi:10.1177/08971900241308624
20. Wei C, He J, Zhang J, et al. The roles and patterns of critical care pharmacists: a literature review and practical operation model in China. *Front Pharmacol*. 2024;15:1439145. PMID: 39568591; PMCID: PMC11576304. doi:10.3389/fphar.2024.1439145
21. Shinoda Y, Ohashi K, Matsuoka T, Arai K, Hotta N, Usami E. Impact of pharmacist-led aminoglycoside stewardship: a 10-year observational study. *J Pharm Health Care Sci*. 2024;10(1):77. PMID: 39609916; PMCID: PMC11605850. doi:10.1186/s40780-024-00399-x
22. Altawalbeh SM, Sallam NM, Al-Khatib M, Alshogran OY, Bani Amer MS. Clinical pharmacist-led medication reconciliation supplemented with medication review in admitted patients with chronic kidney disease: a cost-benefit analysis. *BMJ Open*. 2025;15(2):e087232. PMID: 40010830; PMCID: PMC11865755. doi:10.1136/bmjopen-2024-087232