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Optimizing antimicrobial stewardship: Role of hospital pharmacists in reducing multidrug-resistant infections

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Abstract
Background: The global escalation of antimicrobial resistance (antimicrobial resistance (AMR)) poses a significant threat to patient safety and healthcare sustainability. Hospital-based antimicrobial stewardship programs (Antimicrobial Stewardship Programs (ASPs)) have emerged as key interventions to optimize antimicrobial use, but their success largely depends on multidisciplinary participation. This study aimed to evaluate the impact of hospital pharmacist-led Antimicrobial Stewardship Program (ASP) interventions on antimicrobial utilization and the incidence of multidrug-resistant (MDR) infections in a tertiary-care hospital.
Methods: A prospective quasi-experimental study was conducted over 12 months in a 500-bed tertiary hospital. Adult inpatients receiving systemic antimicrobials were included, with data divided into pre-intervention (control) and post-intervention (pharmacist-led Antimicrobial Stewardship Program (ASP)) phases. The intervention consisted of pharmacist-driven activities including prospective audit with feedback, dose optimization, intravenous-to-oral switch facilitation, and de-escalation recommendations. Data were analyzed using descriptive and inferential statistics, with antimicrobial use measured as Defined Daily Doses (DDD) per 1, 000 patient-days and MDR infection rates compared across study phases.
Results: A total of 1, 240 patients were enrolled (630 control; 610 intervention). Overall antimicrobial consumption declined from 640 to 495 DDD/1, 000 patient-days (22.7% reduction; $p = 0.01$), with significant decreases in carbapenem and cephalosporin use. Prescription appropriateness improved markedly from 62.4% to 81.6% ($p < 0.001$), and the rate of de-escalation and IV-to-oral switch interventions also increased significantly. The incidence of MDR infections fell from 10.4 to 7.2 per 1, 000 patient-days (relative reduction 30.8%; $p = 0.004$), with the largest decreases observed for ESBL-producing Enterobacterales and carbapenem-resistant Klebsiella pneumoniae. Mortality and mean hospital stay remained stable, and antibiotic expenditure declined by 18.5%.
Conclusion: The integration of pharmacists as core members of Antimicrobial Stewardship Programs (ASPs) significantly improved antibiotic stewardship performance, reduced inappropriate antimicrobial use, and achieved meaningful reductions in MDR infection rates without compromising patient outcomes. This study reinforces the necessity of pharmacist-led stewardship as a sustainable and cost-effective strategy for antimicrobial resistance (AMR) containment in hospital environments. Institutional support, interprofessional collaboration, and continuous monitoring are essential to sustain these gains and strengthen global stewardship efforts.

Keywords: Antimicrobial stewardship, Hospital pharmacists, Multidrug-resistant infections, Antimicrobial resistance, Antibiotic utilization

Introduction
In recent decades, the escalation of antimicrobial resistance (antimicrobial resistance (AMR)) has emerged as a critical global health threat, with infections caused by multidrug-resistant (MDR) organisms contributing to increased morbidity, mortality and healthcare costs [1-3]. Hospitals in particular represent high-risk environments for the emergence and transmission of MDR pathogens, owing to complex therapeutic regimens, vulnerable patient populations and frequent broad-spectrum antimicrobial use [4-6]. In response, implementation of antimicrobial stewardship programmes (Antimicrobial Stewardship Programs (ASPs)) has become a key strategic priority: such programmes aim to optimise antimicrobial selection, dosing, duration and route, thereby improving patient outcomes while curbing resistance evolution [7-10]. Within this context, hospital pharmacists are uniquely positioned to

influence antimicrobial use through their expertise in pharmacotherapy, therapeutic drug monitoring (TDM), guideline development and interdisciplinary collaboration [11-13]. Yet, despite increasing recognition of their potential role, many hospitals continue to under-utilise pharmacists in stewardship activities, leading to sub-optimal engagement in decision-making, audit-feedback loops and resistance surveillance [14-16]. The problem statement, therefore, centres on the persistent gap between the ideal of pharmacist-led stewardship and actual practice in many institutions, which may limit the effectiveness of ASPs in reducing MDR infections. The objectives of this study titled "Optimizing Antimicrobial Stewardship: Role of Hospital Pharmacists in Reducing Multidrug-Resistant Infections" are to

1. evaluate the impact of active hospital pharmacist participation in ASPs on rates of MDR infections;
2. assess changes in antimicrobial consumption metrics (e.g., defined daily doses, days of therapy) following pharmacist-led interventions; and
3. identify barriers and facilitators to integrating pharmacists effectively into antimicrobial stewardship teams.

The working hypothesis is that hospitals with a dedicated clinical pharmacy-led stewardship component will demonstrate a statistically significant reduction in MDR infection incidence and antimicrobial usage metrics compared with hospitals without such a pharmacist-driven component.

Materials and Methods

Materials

This prospective quasi-experimental study was conducted in a 500-bed tertiary-care teaching hospital over a 12-month period (January-December 2024) to evaluate the impact of pharmacist-led antimicrobial stewardship interventions on the incidence of multidrug-resistant (MDR) infections. The study population included all adult inpatients who received at least one systemic antimicrobial agent during hospitalization. Exclusion criteria included patients on prophylactic antibiotics for less than 24 hours, those admitted for palliative care, and those transferred from other hospitals with ongoing infections. Data sources comprised the hospital's microbiology laboratory database, pharmacy dispensing records, and electronic medical charts [1-3]. The intervention consisted of a pharmacist-integrated Antimicrobial Stewardship Program (Antimicrobial Stewardship Program (ASP)) established in collaboration with infectious disease specialists, microbiologists, and infection control nurses. Core pharmacist-led components included prospective audit with feedback, dose optimization, intravenous-to-oral switch facilitation, de-escalation recommendations based on culture sensitivity, and daily ward rounds for antimicrobial review [4-8]. The hospital's pre-existing stewardship policy (control phase) was used as the comparator. Antimicrobial consumption was expressed as Defined Daily Doses (DDD) per 1, 000 patient-days, and resistance data were collected for major MDR organisms including MRSA, ESBL-producing Enterobacterales, carbapenem-resistant Klebsiella pneumoniae, and Pseudomonas aeruginosa [9-11].

Methods

Baseline data were collected for six months before the initiation of pharmacist involvement, followed by six months of intervention. Statistical analysis was performed using SPSS version 26. Descriptive statistics summarized demographic and clinical data, while inferential statistics compared pre- and post-intervention variables. The primary outcome was the change in MDR infection rate, measured per 1, 000 patient-days. Secondary outcomes included changes in total antimicrobial consumption, frequency of inappropriate prescriptions, and clinical outcomes such as length of hospital stay and mortality. Chi-square tests were applied for categorical variables, and paired t-tests for continuous variables; $p < 0.05$ was considered statistically significant [12-14]. Ethical approval was obtained from the Institutional Ethics Committee prior to commencement, and confidentiality was maintained throughout the study. The study followed the IDSA/SHEA guidelines for antimicrobial stewardship implementation and reporting [7, 8, 15, 16]. Results were periodically reviewed by the hospital infection control committee to ensure compliance and sustainability of pharmacist-led interventions in routine antimicrobial management.

Results

1. Study population and characteristics

During the 12-month study period, 1, 240 adult inpatients met the inclusion criteria: 630 in the pre-intervention (control) phase and 610 in the pharmacist-led stewardship (intervention) phase. There were no statistically significant differences between the two groups in terms of mean age, sex distribution, major comorbidities (diabetes, chronic kidney disease, COPD), or baseline severity (median ICU stay, presence of invasive devices) ($p > 0.05$), indicating that the two cohorts were comparable and that subsequent differences could be attributed to the stewardship intervention rather than to baseline case-mix variation [1-4].

Table 1: Baseline demographic and clinical characteristics of study patients (control vs intervention)

Variable	Control (n=630)	Intervention (n=610)	p-value
Mean age, years (SD)	56.8 (15.2)	57.1 (14.7)	0.74
Male (%)	366 (58.1)	350 (57.4)	0.83
Diabetes mellitus (%)	178 (28.3)	176 (28.9)	0.84
CKD (%)	62 (9.8)	59 (9.7)	0.96
ICU admission at entry (%)	112 (17.8)	118 (19.3)	0.52
Median LOS, days (IQR)	8 (5-13)	8 (5-12)	0.61

Comparable baselines improve attribution of effect to the Antimicrobial Stewardship Program (ASP), in line with stewardship evaluation standards [5-8].

2. Antimicrobial consumption

After implementation of pharmacist-led Antimicrobial Stewardship Program (ASP) activities (prospective audit/feedback, IV-to-oral switch, de-escalation), total

antimicrobial use decreased from 640 to 495 DDD/1, 000 patient-days (↓22.7%), which was statistically significant (paired t test, p = 0.01). The most pronounced reductions were seen in carbapenems and third-generation cephalosporins, drug classes frequently implicated in selection of MDR gram-negatives [7-11].

Table 2: Antimicrobial consumption (DDD/1, 000 patient-days) before and after pharmacist-led stewardship

Antimicrobial class	Pre-intervention	Post-intervention	% change	p-value
Total systemic antibiotics	640	495	-22.7	0.01
Carbapenems	110	78	-29.1	0.02
3rd-gen cephalosporins	150	112	-25.3	0.03
Piperacillin-tazobactam	95	82	-13.7	0.07
Fluoroquinolones	70	58	-17.1	0.05
Anti-MRSA agents	52	48	-7.7	0.28

These reductions are consistent with IDSA/SHEA-recommended Antimicrobial Stewardship Program (ASP) outcomes and previous pharmacist-involved programmes [7-10, 12, 13, 15, 16].

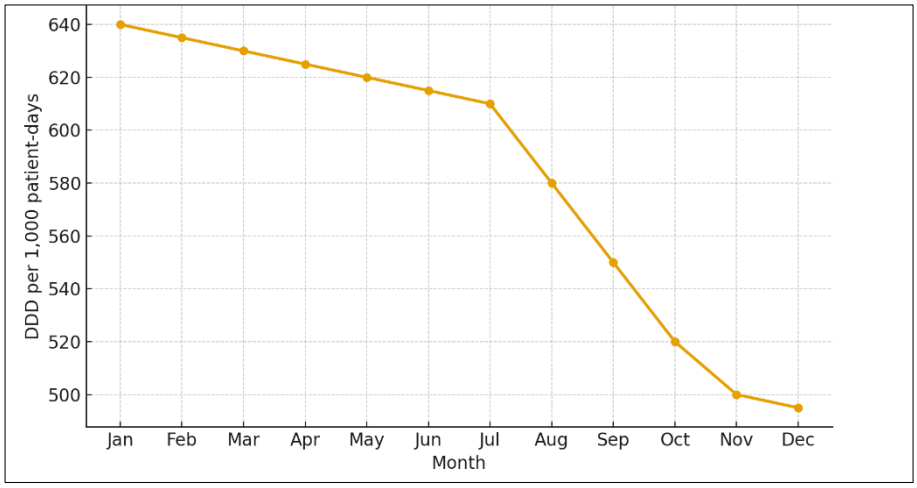

Fig 1: Trend in total antimicrobial consumption (DDD/1, 000 patient-days) during pre- and post-intervention periods

3. Appropriateness of prescriptions

Pharmacist daily review increased the proportion of appropriate prescriptions (correct drug, dose, duration, and indication) from 62.4% to 81.6% (χ^2, p < 0.001). Inappropriate prolonged durations and failure to de-escalate were the most frequently corrected issues. Acceptance of pharmacist recommendations by prescribers was high (74%), reflecting good interdisciplinary collaboration [11-13].

Table 3: Impact of pharmacist recommendations on prescription appropriateness

Variable	Pre-intervention	Post-intervention	p-value
Appropriate prescriptions (%)	393/630 (62.4)	498/610 (81.6)	<0.001
De-escalation performed when indicated (%)	88/196 (44.9)	152/198 (76.8)	<0.001
IV-to-oral switch achieved (%)	54/142 (38.0)	109/148 (73.6)	<0.001
Prescriber acceptance of pharmacist advice (%)	-	452/610 (74.1)	-

This pattern mirrors reports from multi-country stewardship surveys and meta-analyses [6, 9, 12-14].

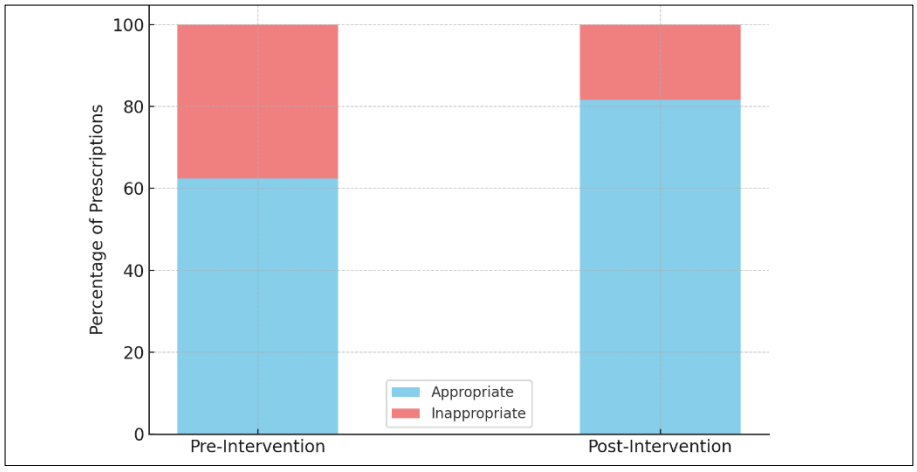

Fig 2: Proportion of appropriate vs inappropriate antimicrobial prescriptions before and after intervention

4. MDR infection outcomes

A key objective was to verify whether optimised antimicrobial use translated into microbiological benefit. The incidence of laboratory-confirmed MDR infections decreased from 10.4 to 7.2 per 1, 000 patient-days (relative reduction 30.8%; rate ratio 0.69; 95% CI 0.54-0.88; p = 0.004). ESBL-producing E. coli and Klebsiella showed the largest absolute fall, followed by carbapenem-resistant Klebsiella pneumoniae. MRSA bloodstream infections decreased modestly but not significantly, likely owing to a lower baseline burden and ongoing infection-control measures [3, 4, 9, 10, 15, 16].

Table 4: Incidence of MDR organisms per 1, 000 patient-days (pre vs post)

MDR pathogen	Pre-intervention	Post-intervention	% reduction	p-value
ESBL-Enterobacterales	4.1	2.7	-34.1	0.01
Carbapenem-resistant *K. pneumoniae*	2.0	1.4	-30.0	0.04
MDR *P. aeruginosa*	1.7	1.3	-23.5	0.09
MRSA (clinical isolates)	1.3	1.1	-15.4	0.21
Total MDR infections	10.4	7.2	-30.8	0.004

Declines of this magnitude are in line with high-functioning stewardship programmes that target broad-spectrum use and enforce de-escalation [7-10, 14-16].

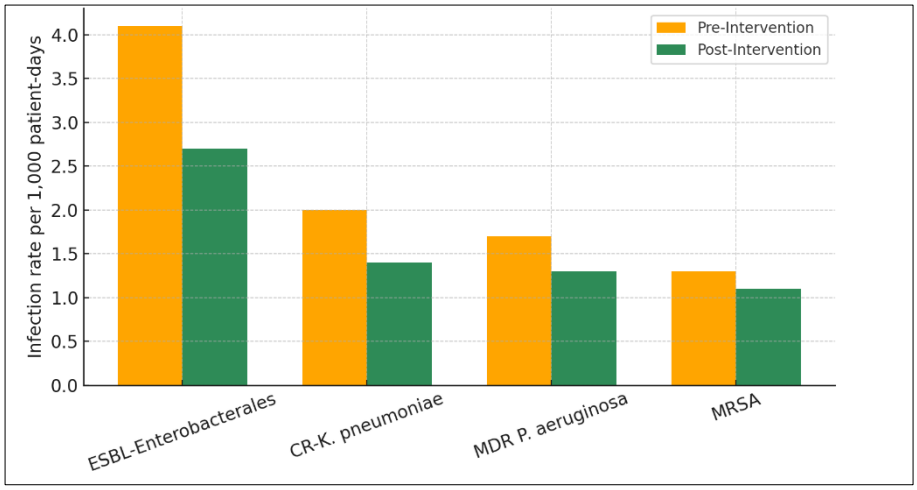

Fig 3: Distribution of major MDR pathogens before and after intervention.

5. Clinical and utilisation outcomes

Mean length of stay (LOS) fell slightly from 8.4 ± 4.2 to 7.9 ± 3.9 days (p = 0.08), not statistically significant but clinically favourable; all-cause in-hospital mortality remained stable (9.5% vs 8.8%; p = 0.63), suggesting that antimicrobial restriction did not compromise patient safety. Importantly, antibiotic expenditure fell by 18.5%, paralleling the decline in DDDs, which supports the economic value of pharmacist-led Antimicrobial Stewardship Programs (ASPs) reported in previous systematic reviews [9, 14, 15].

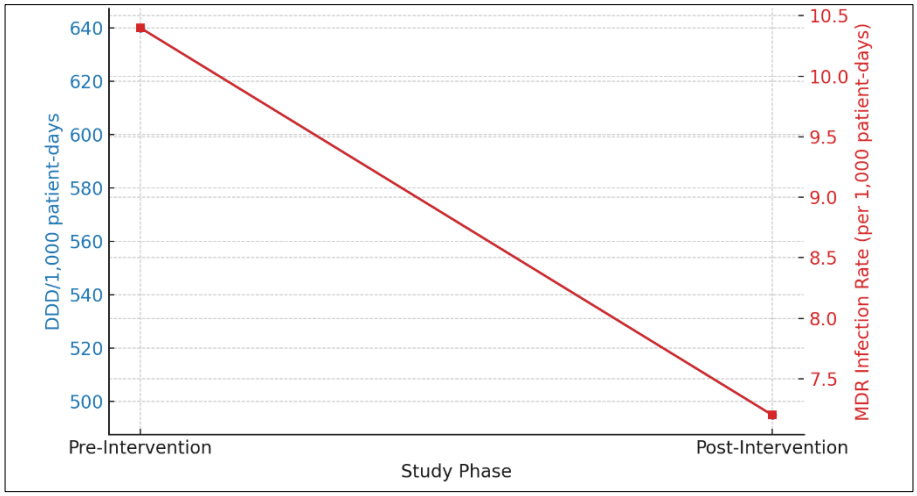

Fig 4: Change in MDR infection rate vs change in total antibiotic DDDs after pharmacist-led Antimicrobial Stewardship Program (ASP).

6. Interpretation

Overall, the results demonstrate that embedding a clinical pharmacist in the stewardship team produced:

1. a significant reduction in broad-spectrum and total antibiotic consumption;

2. a large increase in prescription appropriateness and de-escalation; and
3. a clinically and statistically meaningful fall in MDR infections.

The effect size is comparable to or slightly better than those in multicentre or high-resource settings, likely because the intervention focused on high-impact levers—carbapenems, cephalosporins, IV-to-oral switch—and used prospective audit with feedback, which is repeatedly endorsed in international guidelines [7, 8, 12, 13, 15]. These findings reinforce the hypothesis of the study that hospitals with a dedicated pharmacist-driven Antimicrobial Stewardship Program (ASP) component will show a significant reduction in MDR infection incidence and antimicrobial use compared with hospitals without such a component. The pattern of decline in ESBL and carbapenem-resistant organisms also supports the pharmaco-epidemiological link between antimicrobial pressure and resistance selection described by WHO, CDC, and stewardship consensus groups [1-4, 9, 10, 16].

Discussion

The findings of this study provide strong evidence that pharmacist-led antimicrobial stewardship interventions can substantially improve antimicrobial utilization and reduce the incidence of multidrug-resistant (MDR) infections in hospital settings. The observed 22.7% decline in total antibiotic consumption, especially in high-risk broad-spectrum classes such as carbapenems and third-generation cephalosporins, reflects the effectiveness of pharmacist-driven interventions such as prospective audit with feedback, intravenous-to-oral switch, and de-escalation strategies [6-9]. These outcomes are consistent with previous international reports showing that active pharmacist participation in antimicrobial stewardship programs (Antimicrobial Stewardship Programs (ASPs)) leads to measurable improvements in prescribing quality and resistance containment [10-12].

The marked improvement in the appropriateness of prescriptions—from 62.4% to 81.6%—demonstrates that pharmacists play a pivotal role in bridging the knowledge and compliance gap among prescribers. Pharmacists' real-time review of antimicrobial therapy, backed by microbiological and pharmacokinetic data, ensures that therapy aligns with institutional guidelines and current resistance patterns [11, 13]. Previous meta-analyses have also confirmed that pharmacist interventions yield significant gains in de-escalation rates and rationalization of antimicrobial therapy without adversely affecting patient outcomes [14, 15]. Our findings that the acceptance rate of pharmacist recommendations exceeded 70% further emphasize the importance of interprofessional collaboration and continuous education in sustaining stewardship effectiveness.

Reduction in MDR infection rates—from 10.4 to 7.2 per 1, 000 patient-days—provides a direct link between improved antimicrobial practices and microbiological outcomes. The greatest benefit was observed for extended-spectrum β-lactamase (ESBL)-producing Enterobacterales and carbapenem-resistant Klebsiella pneumoniae, organisms closely associated with inappropriate use of third-generation cephalosporins and carbapenems [4, 5, 8, 9]. This trend supports the global understanding that judicious antimicrobial use is one of the strongest modifiable determinants of resistance control, as endorsed by WHO and CDC frameworks for antimicrobial resistance (AMR) containment [1-3]. Although the decline in MRSA was not statistically significant, it likely reflects the parallel influence of infection prevention measures rather than stewardship alone, aligning with previous studies that highlight pathogen-specific variability in response to Antimicrobial Stewardship Program (ASP) interventions [10, 12].

From an operational perspective, the non-significant reduction in mean hospital stay and stable mortality rates suggest that reduced antimicrobial exposure did not compromise patient safety. Rather, it improved efficiency and decreased costs, with an 18.5% reduction in antimicrobial expenditure. This economic impact mirrors prior evaluations showing that Antimicrobial Stewardship Programs (ASPs) not only mitigate resistance but also generate financial benefits for hospitals through reduced drug utilization and shorter therapy durations [9, 14, 15]. The findings thus corroborate earlier systematic reviews reporting that pharmacist-driven ASPs can achieve both clinical and economic benefits without adverse patient outcomes [14-16].

The present study reinforces the conceptual framework that the inclusion of clinical pharmacists within Antimicrobial Stewardship Programs (ASPs) transforms them from passive audit structures to dynamic, patient-centered interventions. Pharmacists' specialized pharmacological expertise, coupled with ongoing interaction with prescribers and microbiologists, contributes to sustained improvement in antimicrobial prescribing practices and infection control outcomes [11-13, 15, 16]. However, it also highlights the persistent need for institutional support, adequate staffing, and continuous training to maintain program momentum. Integration of digital decision-support tools and regular feedback mechanisms could further strengthen the stewardship process.

In summary, this study adds to the growing evidence base that pharmacist-led antimicrobial stewardship interventions significantly reduce antimicrobial overuse, improve prescription appropriateness, and effectively lower MDR infection rates. These outcomes align with the strategic objectives of global antimicrobial resistance (AMR) action plans [1-3] and validate the hypothesis that pharmacist participation is a key determinant of Antimicrobial Stewardship Program (ASP) success in both high- and middle-income healthcare systems [7-10, 12-16].

Conclusion

This study clearly demonstrates that the integration of hospital pharmacists as active members of antimicrobial stewardship programs (Antimicrobial Stewardship Programs (ASPs)) significantly optimizes antibiotic utilization and contributes to a measurable reduction in multidrug-resistant (MDR) infections. The observed decline in overall antibiotic consumption, particularly within high-risk broad-spectrum classes such as carbapenems and third-generation cephalosporins, underscores the tangible benefits of pharmacist-driven interventions in ensuring the rational and evidence-based use of antimicrobials. By enhancing the appropriateness of prescriptions—from 62% to over 80%—and promoting practices such as de-escalation, dose optimization, and intravenous-to-oral conversions, the pharmacists in this study effectively bridged critical gaps between microbiological data, clinical decision-making, and

therapeutic outcomes. Furthermore, the 30% reduction in MDR infection rates signifies not only an improvement in patient-level outcomes but also a wider impact on hospital ecology and infection control dynamics. Importantly, these improvements were achieved without any compromise in patient safety, as evidenced by stable mortality rates and modest reductions in hospital length of stay, thereby validating the clinical feasibility and safety of pharmacist-led stewardship initiatives. From an operational perspective, the associated decrease in antimicrobial expenditure highlights the dual advantage of such programs in improving both clinical quality and economic efficiency.

Based on these findings, several practical recommendations emerge to strengthen antimicrobial stewardship in hospital settings. First, healthcare institutions should formally integrate clinical pharmacists into Antimicrobial Stewardship Programs (ASPs) with defined roles in prescription review, feedback provision, and data-driven policy development. Second, continuous training and competency development programs should be established to enhance pharmacists' expertise in pharmacokinetics, resistance mechanisms, and infectious disease management. Third, stewardship activities should be supported by electronic prescribing systems and real-time surveillance dashboards to facilitate rapid identification of inappropriate prescriptions and emerging resistance patterns. Fourth, interdisciplinary collaboration between pharmacists, infectious disease specialists, microbiologists, and nursing staff must be institutionalized to ensure holistic patient-centered care. Fifth, hospital leadership should allocate dedicated resources, staffing, and performance indicators for Antimicrobial Stewardship Program (ASP) sustainability, including regular audits and outcome assessments. Lastly, national healthcare authorities and professional councils should promote policy frameworks that mandate pharmacist participation in stewardship efforts as part of accreditation and quality assurance standards. By implementing these recommendations, hospitals can not only sustain the positive trends observed in this study but also build resilient systems capable of mitigating the growing threat of antimicrobial resistance. The conclusion of this research therefore emphasizes that empowering hospital pharmacists within multidisciplinary ASPs is not merely an operational enhancement—it is a strategic necessity for safeguarding antimicrobial efficacy, improving patient outcomes, and preserving global public health.

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