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Review Article

Implementation Strategies And Outcomes Of Pharmacist-Led Antimicrobial Stewardship Programs: Global Evidence And The Indian Scenario

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ABSTRACT

Antimicrobial resistance has become a major concern for healthcare systems worldwide, largely due to the inappropriate and excessive use of antibiotics. Many nations have implemented antimicrobial stewardship programs (ASPs) to address this problem, where pharmacists are increasingly playing active clinical roles in encouraging the prudent and safe use of antibiotics. With a focus on the Indian healthcare system, this narrative study assesses various pharmacist-led ASP models, their results, and the practical difficulties in putting them into practice. Systematic reviews, observational studies, interventional research, and policy reports were among the pertinent papers that were found using databases like PubMed, Scopus, and Google Scholar and published between 2015 and 2025. The results show that pharmacist-led stewardship programs help improve adherence to treatment guidelines, reduce unnecessary use of broad-spectrum antibiotics, lower the incidence of Clostridioides difficile infections, and decrease healthcare costs .However, a number of variables, including institutional backing, the availability of qualified pharmacists, and the particular implementation approach employed, frequently affect these programs' overall efficacy. Initial research in India has demonstrated promising gains in surgical prophylaxis compliance and antimicrobial prescribing practices, but broader adoption is still challenging due to infrastructural limitations,

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, conventional prescribing hierarchies, and limited worker capacity. Overall, pharmacist-led ASPs have a lot of potential for enhancing patient safety and maximizing the use of antibiotics; but, for long-term success, particularly in settings with limited resources, tighter integration, improved clinical pharmacy training, and standardized assessment techniques are required.

INTRODUCTION

Antimicrobial resistance is increasingly recognized as one of the most serious public health challenges of the twenty-first century. Approximately 1.27 million fatalities globally in 2019 were directly caused by bacterial antimicrobial resistance, which also led to approximately 4.95 million deaths linked to resistant diseases.[1] The Global Burden of Disease Study 2021 projects that between 2025 and 2050, antimicrobial resistance may cause nearly 39 million deaths, with the highest burden anticipated among the elderly and populations in low- and middle-income countries, if effective and sustained interventions are not implemented.[2] Based on data from over 23 million laboratory-confirmed cases in 110 countries, the World Health Organization's 2025 Global Antimicrobial Resistance and Use Surveillance System report emphasizes that resistance to commonly used antibiotics is not only widespread but also steadily rising across various regions. Over 40% of bacteria-drug combinations showed a rise in resistance to at least one monitored antibiotic between 2018 and 2023, according to the analysis.[3] Irrational antibiotic prescription in clinical practice remains one of the main avoidable sources of antimicrobial resistance. Practices such as inappropriate empirical therapy, incorrect dosing, prolonged prophylactic use, and failure to modify treatment according to culture and sensitivity findings significantly increase selective pressure on microorganisms, thereby accelerating the emergence and spread of resistant strains.[4,5]

Addressing these prescribing failures is the central mandate of antimicrobial stewardship programs, which have been broadly advocated by international bodies including the WHO, the Infectious Diseases Society of America (IDSA), and the Society for Healthcare Epidemiology of America (SHEA).Pharmacists have emerged as indispensable contributors to stewardship efforts by virtue of their specialized competencies in pharmacotherapy, pharmacokinetics, drug interaction management, and therapeutic monitoring. Systematic reviews and meta-analyses confirm that pharmacist led or pharmacist supported stewardship interventions are associated with statistically significant improvements in prescribing appropriateness, reductions in antimicrobial consumption, and better clinical outcomes.[6,7] Despite this evidence base, the global landscape of pharmacist led antimicrobial stewardship programs implementation remains heterogeneous, and the specific models that optimize outcomes in resource limited settings including India are incompletely characterized.

India faces an antimicrobial resistance burden that is among the most severe globally. Gram-negative pathogens such as *Klebsiella pneumoniae* and *Acinetobacter baumannii* demonstrate exceptionally high rates of carbapenem resistance in Indian tertiary care facilities.[8] Pharmacists are important members of antimicrobial stewardship teams, according to the Indian Council of Medical Research and the National Action Plan on Antimicrobial Resistance (2017–2021). However, the implementation of these programs in India's healthcare settings is still uneven because of a number of structural, educational, and cultural issues.[9,10] Prior reviews of pharmacist-led antimicrobial stewardship programs have mostly focused on high-income nations or have only provided descriptive summaries without critically analysing various implementation strategies or

investigating the causes of program outcome variations. By rigorously examining available data on the implementation tactics of pharmacist-led antimicrobial stewardship programs and evaluating their clinical, microbiological, and financial effects, this review seeks to overcome these constraints. Comparing the efficacy of various stewardship models and analysing their suitability for the Indian healthcare system have received special attention. The assessment also identifies significant areas that call for more study and policy-level funding, particularly in low- and middle-income nations.

2. METHODOLOGY

This critical narrative review was carried out using a structured and reproducible search strategy. Electronic databases searched included PubMed/MEDLINE, Scopus, and Google Scholar, restricted to publications from January 2009 to March 2025. The terms "antimicrobial stewardship program," "antimicrobial stewardship pharmacist," "pharmacist-led intervention antibiotic," "antimicrobial resistance India," "antibiotic prescribing optimization," "clinical pharmacist stewardship outcomes," "ICMR antimicrobial guidelines," and "AMS low-income country" were used both singly and in Boolean combinations. Systematic reviews and meta-analyses, randomized and non-randomized interventional studies, interrupted time series analyses, prospective and retrospective observational cohort studies, point prevalence surveys, and national policy or guideline papers were among the research designs that qualified. Research was incorporated if it (i) assessed pharmacist-led treatments or roles within an ASP; (ii) reported at least one measurable clinical, microbiological, or economic result; and (iii) were carried out in ambulatory, hospital, or mixed care settings. Studies lacking peer review or official policy status, or those restricted to the use of antibiotics in veterinary or agricultural settings, were not included. Quantitative pooling was not carried out due to the diversity of study designs, demographics, and outcome measures found. Rather, a narrative synthesis technique was used to arrange the results according to the kind of implementation model, the outcome domain, and the healthcare context. During synthesis, the quality of the included research was taken into account. Higher-quality data (systematic reviews, randomized trials, and interrupted time series analyses over single site observational studies) was preferred when many studies addressed the same outcome. Insufficient evidence is indicated, and conclusions are qualified to demonstrate the degree of evidence supporting each finding.

3. THE CLINICAL PHARMACIST IN ANTIMICROBIAL STEWARDSHIP: SCOPE AND EVIDENCE

3.1 Core Stewardship Functions

Pharmacists play a vital role in antimicrobial stewardship programs through a range of clinical and quality improvement activities. Reviewing antimicrobial prescriptions, keeping an eye on proper medication selection and dosage, verifying treatment length, and guaranteeing adherence to hospital policies are some of their duties. Prospective audit and feedback (PAF) is regarded as one of the best stewardship techniques among these treatments. This method involves pharmacists reviewing antimicrobial medication on a frequent basis and advising prescribers on treatment optimization, de-escalation, dosage change, or cessation as needed.[6] International research provides compelling evidence for the efficacy of PAF therapies guided by pharmacists. Dighriri et al. carried out a meta-analysis and systematic review in 2023, which comprised 47 investigations, found that pharmacist participation

via PAF greatly enhanced treatment compliance and decreased needless antimicrobial medication duration.[6] These results demonstrate the increasing significance of pharmacists as proactive participants in the prudent use of antibiotics and the avoidance of resistance in hospital environments. Complementary functions include formulary restriction management, intravenous to oral (IV-to-PO) conversion programs, renal dose adjustment review, and therapeutic drug monitoring coordination. Beyond direct prescription review, pharmacists contribute to institutional antimicrobial governance through antibiogram development and interpretation, local guideline and clinical decision support tool creation, point prevalence survey coordination, antimicrobial utilization reporting using defined daily dose (DDD) methodology, and continuing education of prescribers and nursing staff.[12] A 20-year systematic review by Nampoothiri et al. (2025) traced the evolution of pharmacist stewardship roles across healthcare systems, documenting a progressive shift from dispensary-based functions toward integrated clinical decision making a transition that is associated with improved stewardship program performance.[11]

3.2 Comparative Effectiveness of Stewardship Models

Four principal implementation models characterize pharmacist-led Antimicrobial stewardship programs in the published literature, and their comparative effectiveness represents a critical and underexplored dimension of the evidence base. Table 1 summarizes the mechanisms, supporting evidence, and identify the limitations of each model.

Table 1. Principal pharmacist led Antimicrobial stewardship programs implementation models: mechanisms, evidence, and limitations.

Model	Core Mechanism	Key Evidence	Limitations
Prospective Audit & Feedback (PAF)	Post-prescribing pharmacist review with structured recommendations	Meta-analysis: improved guideline concordance, reduced duration (Dighriri et al., 2023; Lee et al., 2022)	Resource intensive; requires pharmacist access to real time clinical data
Formulary Restriction	Prior authorization required for broad-spectrum/reserve-class agents	Reduces carbapenem/colistin use; associated with improved resistance patterns	Risk of delayed therapy; potential clinician resistance
IV-to-Oral Conversion	Pharmacist-initiated switch when clinical criteria are met	Reduces hospital stay duration ; comparable clinical outcomes	Requires robust patient monitoring systems
Educational Outreach	Prescriber training, guideline dissemination, audit feedback reports	Improves knowledge scores; modest prescribing impact when used alone	Effect attenuates over time without reinforcement

Current evidence indicates that no single antimicrobial stewardship model is universally superior across all healthcare settings. While educational interventions alone usually result in only modest and short-term improvements in prescribing practices, prospective audit and

feedback (PAF) and formulary restriction strategies consistently show the strongest and most sustained reductions in inappropriate antimicrobial consumption.[13] Research assessing combined stewardship strategies also indicates that combining PAF with formulary limitation may result in additional benefits and improve prescription compliance more successfully than separate treatments.[14] However, rather of using randomized controlled trials, a large portion of the comparative stewardship literature uses interrupted time series and before-and-after research designs, which reduces the robustness of causal inferences.

3.3 Pharmacist Stewardship Beyond Hospital Inpatient Settings

Pharmacists now have a far wider role in antimicrobial stewardship than only providing inpatient hospital treatment. By limiting the sale of antibiotics without a prescription, advising patients on the proper use of antibiotics, and encouraging adherence to recommended treatment, pharmacists in community pharmacy settings support stewardship. These interventions have demonstrated measurable reductions in unnecessary antibiotic acquisition, particularly in regions where dispensing regulations are inadequately enforced.[15] During the COVID-19 pandemic, pharmacists worked as essential stewardship professionals by helping reduce inappropriate antibiotic prescribing associated with viral respiratory infections. They also played a critical role in managing antimicrobial supplies during periods of drug shortages, rapidly changing clinical guidelines, and increased healthcare system pressure.[16]

4. THE ANTIMICROBIAL RESISTANCE LANDSCAPE: GLOBAL AND REGIONAL DIMENSIONS

4.1 Epidemiological Burden

The global epidemiology of antimicrobial resistance is characterized by increasing resistance prevalence across nearly all pathogen drug combinations of clinical significance. WHO GLASS 2025 data indicate that *Escherichia coli* resistance to third-generation cephalosporins exceeds 40% globally and surpasses 70% in parts of sub-Saharan Africa, while *Klebsiella pneumoniae* resistance to the same class exceeds 55% in many regions.3 Carbapenem-resistant *Acinetobacter baumannii* classified as a Priority 1 (Critical) pathogen in the updated 2024 WHO Bacterial Priority Pathogens List is responsible for a disproportionate share of ICU associated mortality in LMICs.[3,17]

GBD 2021 analysis demonstrates that antimicrobial resistance mortality trends from 1990 to 2021 show a concerning increase among adults aged 70 years and above, and that absolute antimicrobial resistance attributable deaths are highest in South Asia and sub-Saharan Africa.2 In India specifically, studies have documented carbapenem resistance rates exceeding 50–60% among *K. pneumoniae* and *A. baumannii* clinical isolates in tertiary care settings among the highest rates recorded globally.[8]

4.2 Drivers of Resistance and the Stewardship Imperative

Antimicrobial resistance develops mainly because of improper and excessive antibiotic use. When antibiotics are given in low or inadequate doses, bacteria are exposed to the drug without being completely destroyed, allowing resistant strains to survive and multiply. The unnecessary use of broad-spectrum antibiotics without culture or sensitivity testing also disturbs the normal microbial flora and encourages the growth of resistant organisms. Another major issue,

especially in Indian surgical practice, is prolonged antimicrobial prophylaxis. Antibiotics are often continued for longer than required, even after the beneficial period has passed, which increases resistance among skin and gut bacteria.[4,5] The AID (Antimicrobial, Infection Prevention, and Diagnostic) Stewardship model proposed by Dik et al. in 2017 explains that antimicrobial stewardship should work together with infection prevention and proper diagnostic practices.[18] The model emphasizes the strong relationship between prompt laboratory diagnosis and efficient infection management strategies and the prudent use of antibiotics. Instead of waiting two to three days, more recent quick diagnostic methods like syndromic PCR panels and MALDI-TOF mass spectrometry may yield results in a matter of hours. This lessens the needless use of broad-spectrum antibiotics and enables doctors to begin focused therapy earlier.[19] By analysing test results, keeping an eye on treatment, and assisting physicians with audits and comments, pharmacists play a crucial part in this process.

Antimicrobial prescription trends in hospitals and healthcare systems are now often studied using point prevalence surveys. Hospitals in South and Southeast Asia often use more broad-spectrum antibiotics and treat patients for longer periods of time than hospitals in Europe, according to reports from the Global Point Prevalence Survey network.[20] These surveys assist hospitals in identifying patterns of incorrect prescriptions and tracking the long-term efficacy of antimicrobial stewardship initiatives.

5. CLINICAL, MICROBIOLOGICAL, AND ECONOMIC OUTCOMES: GLOBAL EVIDENCE

5.1 Clinical and Patient Safety Outcomes

Pharmacist-led antimicrobial stewardship programs are linked to improved clinical and patient safety outcomes, according to a number of systematic studies and meta-analyses. Through proper medication selection, dosage optimization, treatment duration monitoring, and minimizing needless antimicrobial exposure, pharmacists contribute to better antibiotic usage. These measures reduce the likelihood of adverse medication responses, treatment failure, and antimicrobial resistance in addition to supporting rational prescription. Pharmacist-led stewardship programs in emergency rooms were assessed in a systematic review and meta-analysis by Lee et al. in 2022. The results showed notable improvements in effective antibiotic prescribing practices as well as decreases in needless treatment length. The study demonstrated the beneficial effects of pharmacist participation on overall patient safety outcomes and antibiotic usage.[21] Hospital onset *Clostridioides difficile* infection (CDI) rates represent the most consistently reported patient safety metric; multiple cohort studies and time series analyses associate ASP implementation with *Clostridioides difficile* infection incidence reductions of 15–50%.[22] A systematic review by Saha et al. (2021) identified statistically significant reductions in *Clostridioides difficile* infection and antimicrobial-related adverse events attributable to pharmacist led services across diverse hospital settings.[23] Outcomes data for critically ill patients are more heterogeneous. Several prospective studies report improved clinical cure rates and 30-day mortality reductions associated with pharmacist led sepsis protocol adherence and pharmacokinetic optimization, though study designs rarely permit adjustment for confounding by illness severity.[24] Perioperative stewardship programs involving pharmacists have shown consistent improvements in surgical prophylaxis timing, agent selection, and post operative discontinuation, with corresponding reductions in

surgical site infection (SSI) rates in meta-analysis.[25]

5.2 Microbiological Outcomes

The effect of Antimicrobial stewardship programs on resistance ecology is mechanistically plausible but methodologically challenging to demonstrate, given the multifactorial determinants of institutional resistance patterns and the long-time horizons required to detect change. Available evidence, predominantly from interrupted time-series studies spanning three to ten years, suggests that sustained reductions in carbapenem and fluoroquinolone consumption are associated with measurable declines in the incidence density of carbapenem-resistant *Enterobacter ales* and multidrug-resistant *Pseudomonas aeruginosa* within individual institutions.[26] However, the magnitude of this effect is modest relative to background trends, and evidence of true de-escalation of institutional resistance rather than mere temporal coincidence remains limited. Reviewers should exercise caution in interpreting observational microbiological outcomes as causally attributable to pharmacist stewardship activity.

5.3 Economic Outcomes

Pharmacist-led Antimicrobial stewardship programs demonstrate a favourable return on investment across institutional contexts. Direct cost savings are generated primarily through substitution of expensive broad-spectrum agents with narrower-spectrum alternatives, reduced treatment duration, and decreased *Clostridioides difficile* infection -related care costs.[27] A comprehensive economic evaluation by Anderson et al. (2020) in an academic medical centre documented net annual savings exceeding USD 900,000 attributable to pharmacist driven stewardship interventions after accounting for program costs.[27] Systematic reviews of cost outcomes consistently report net savings, though estimates vary considerably depending on baseline antimicrobial expenditure, institutional formulary structure, and the attribution methodology employed.

Economic analyses of Antimicrobial stewardship programs are highly susceptible to methodological heterogeneity, including variability in which cost categories are included, whether incremental cost-effectiveness is calculated, and whether long run resistance costs are model. The current evidence base is insufficient to derive generalizable cost-effectiveness estimates across healthcare contexts, and this represents an important priority for future health economic research.

6. PHARMACIST-LED ANTIMICROBIAL STEWARDSHIP IN INDIA

6.1 Policy and Regulatory Context

India's national antimicrobial resistance policy trajectory has progressively elevated the status of pharmacy professionals within the stewardship architecture. An ICMR survey conducted in 2013 assessed ASP capabilities across 20 tertiary institutions and revealed critical deficiencies: the majority of hospitals lacked structured stewardship programs, and clinical pharmacist participation in existing initiatives was minimal.[28] These findings catalysed the development of the National Action Plan on antimicrobial resistance (NAP-ANTIMICROBIAL RESISTANCE 2017–2021), which formally incorporated pharmacist integration into its strategic objectives, and the ICMR's 2018 Antimicrobial Stewardship Program Guidelines, which constituted the first national policy document to define pharmacists as core members of multidisciplinary AMS teams

alongside infectious disease physicians, clinical microbiologists, and infection control professionals.[10]

There is a significant institutional push for the implementation of antimicrobial stewardship programs, particularly in private corporate hospitals, as a result of the accreditation standards established by the National Accreditation Board for Hospitals and Healthcare Providers (NABH).[10] Wider use of stewardship initiatives has been driven by the growing requirement that hospitals pursuing accreditation adhere to organized antibiotic use rules, infection control procedures, and prescription tracking systems. Despite managing a significantly higher incidence of infections associated with antibiotic resistance, government-run tertiary care institutions continue to fall behind in the implementation of good stewardship. The growth and durability of stewardship initiatives inside India's public healthcare system remain limited by a lack of funding, poor facilities, a lack of qualified staff, and administrative difficulties.

6.2 Implementation Models in the Indian Context

In Indian tertiary care institutions, clinical pharmacist participation in antimicrobial stewardship programs often adheres to global stewardship principles, while it is frequently adjusted based on local workforce, infrastructure, and resource availability.

1.Integrated Multidisciplinary Team Model: Pharmacists collaborate with microbiologists and infectious disease specialists in multidisciplinary antimicrobial stewardship (AMS) teams in major corporate hospital networks. They review current antimicrobial therapy, take part in bedside ward rounds, and provide prescribers immediate suggestions.[29] Research has indicated that regular engagement and professional collaboration during ward rounds, in contrast to delayed retrospective consultation, increases the likelihood that pharmacist suggestions will be adopted.

2.Pharmacy Driven Prospective Audit and Feedback: In many hospitals, especially where pharmacists are not routinely included in clinical ward rounds because of institutional hierarchy or workforce limitations, prospective audit and feedback remains the most commonly used stewardship approach. In this model, stewardship pharmacists review antimicrobial prescriptions independently and provide written or verbal recommendations to the treating team. This approach has shown measurable improvements in empirical antibiotic selection, prescription appropriateness, and clinical documentation quality.[30]

3.Formulary Restriction and Prior Authorization: Hospitals with more established stewardship programs have introduced formulary restriction systems for selected reserve antibiotics. Under this model, pharmacists or infectious disease specialists must approve the use of high-end antimicrobials such as carbapenems, colistin, and glycopeptides before dispensing. This strategy helps reduce unnecessary use of broad spectrum and last resort antibiotics while promoting more rational antimicrobial prescribing practices.[31]

4.Surgical Prophylaxis Optimization: Given the high prevalence of inappropriate prophylaxis in Indian surgical practice with studies documenting prophylaxis continuation for five to seven days post operatively rather than the evidence-based 24-hour maximum pharmacist led surgical prophylaxis protocols have produced some of the most tangible outcomes data in the Indian literature.[32]

6.3 Outcome Evidence from Indian Studies

Published outcome data from Indian pharmacist led Antimicrobial stewardship programs , while encouraging, must be interpreted with appropriate acknowledgment of methodological limitations. The majority of available studies are single centre, before after designs without control groups, conducted predominantly in private tertiary care hospitals in South India a setting that may not be representative of the broader Indian healthcare ecosystem. Table 2 summarizes selected studies.

Table 2. Selected pharmacist led Antimicrobial Stewardship Program outcome studies from Indian healthcare settings. DDD = defined daily dose; ID : Infectious Disease.

Study / Setting	Intervention	Key Outcome(s)
Tertiary care, Kerala, South India (Nampoothiri et al., 2021)[33]	Multidisciplinary clinical pharmacist-driven AMS program	Appropriateness of antimicrobial prescriptions increased from 56% (742/1326) in year 1 to 80% (1752/2190) by year 3; compliance with AMS recommendations rose from 54% to 70%
Tertiary Care, Gurgaon, North India (Jaggi, Nirwan & Chakraborty, 2018)[41]	Prospective 29-month antibiotic audit (Jan 2014–May 2016) of clean and clean-contaminated surgeries, evaluating adherence to presurgical antibiotic prophylaxis against three parameters: antibiotic choice, timing, and duration	Of 1,501 audited surgeries: 87.3% compliance for appropriate antibiotic selection, 85.3% for appropriate timing of administration, but only 34.9% for appropriate duration
Tertiary care, Western Maharashtra (Attar et al., 2025)[39]	AMS program with pharmacist involvement, ICMR-guided	Overall antibiotic consumption reduced from 1,681.0 to 1,420.0 DDD/100 bed-days; notable reductions in ceftriaxone, piperacillin-tazobactam, and amikacin use
Multi-centre private hospitals, India (Warrier et al., 2025)[40]	Pharmacist-driven feedback on restricted antibiotics (in the absence of ID physicians)	Reported significant decrease in restricted antibiotic prescriptions and days of therapy (DOT), with increased compliance to hospital antibiotic policy

Despite these methodological caveats, the consistency of direction across independent studies all reporting improvements in prescribing quality indicators provides reasonable confidence that pharmacist led interventions are associated with meaningful stewardship benefits in the Indian context. What remains absent from the published evidence base are multicentre randomized or quasi experimental studies with adequate control groups, long term follow up data beyond 12 months, and outcome data from public sector district and secondary level hospitals where antimicrobial misuse may be most prevalent and unmonitored.[33]

6.4 Barriers to Implementation: A Critical Analysis

The implementation of pharmacist-led antimicrobial stewardship programs in India is

affected by several interconnected systemic, professional, and infrastructural barriers that collectively hinder the development and sustainability of these programs. The inadequate clinical focus of pharmacy education in India is one of the biggest barriers. With comparably less focus on clinical pharmacotherapy, the majority of graduates from B.Pharm and M.Pharm schools are largely trained in pharmaceutical sciences. Because of this, a large number of pharmacists lack sufficient knowledge of clinical decision-making, bedside communication, infectious illnesses, and antimicrobial stewardship procedures.[34] PharmD graduates still make up a very small percentage of the pharmacy workforce overall, and the quality of clinical training varies greatly between institutions, despite the introduction of PharmD programs after 2008 bringing greater clinical exposure and patient-focused training.[35]

The strong professional hierarchy seen in the Indian healthcare system is another significant barrier. Even when pharmacist suggestions are backed by solid clinical data, doctors maintain nearly total control over treatment choices in many institutions.[36] Although this problem is present in many healthcare settings throughout the world, traditional views about professional duties and responsibilities make it more noticeable in India. As a result, pharmacists engaged in antimicrobial stewardship frequently have to build confidence over time by communicating with medical teams in a consistent, evidence-based, and cooperative manner. Long-term involvement and consistent multidisciplinary collaboration are often necessary to establish such professional confidence.

Limitations on resources at public hospitals, such as a lack of pharmacists on staff, Limited availability to fast microbiological culture findings and automated prescription systems significantly limit the viability of treatment monitoring models and PAF that rely on real-time data.[37] The lack of consistent, verified performance indicators for Indian antimicrobial Stewardship initiatives further hinder program assessment and the creation of evidence-based justifications for administrative expenditures.

7. DISCUSSION

Pharmacist-led antimicrobial stewardship programs correspond to significant improvements in antimicrobial prescribing practices, patient safety, and healthcare costs across various hospital settings globally, according to the data evaluated in this study. However, while interpreting these results, a number of significant caveats must be taken into account. The majority of the evidence that is currently available comes from a single centre. observational research with before-and-after designs, which restricts the results' overall strength. Potential confounding variables such concurrent infection control programs, differences in patient demographics, and shifting trends in antibiotic availability were not sufficiently controlled in many trials. Even though quasiexperimental studies and interrupted time-series analyses offer comparatively greater evidence, they are still unable to prove a direct causal relationship. To provide more trustworthy comparative effectiveness data, future research should concentrate on multicentre pragmatic trials and stepped-wedge cluster randomized studies.

The major variation in stewardship program execution among studies, which makes it challenging to find a model that is generally ideal, is another significant issue. According to available data, programs that combine antibiotic restriction measures with prospective audit and feedback may be more successful than single treatments. In a similar vein, stewardship initiatives seem to provide greater results when pharmacists

participate in interdisciplinary clinical teams as opposed to carrying out standalone pharmacy-based assessments. The best stewardship strategy for healthcare environments with low resources is still up for debate, especially in situations where there are few or no computerized prescription systems, trained stewardship pharmacists, or quick diagnostic facilities.

Careful interpretation is also necessary for the microbiological results presented in stewardship studies. Reductions in antibiotic resistance patterns after stewardship deployment are supported by current resistance management techniques and are physiologically reasonable. However, a number of interrelated factors, such as diagnostic stewardship programs, environmental cleaning techniques, and infection control strategies, have an impact on resistance patterns. Attributing advances only to antimicrobial stewardship initiatives may oversimplify a very complicated process due to these overlapping factors and the delayed nature of resistance development.

There is currently insufficient information to make firm judgments on the extent of the advantages of pharmacist-led antimicrobial stewardship initiatives in the Indian healthcare system. Nonetheless, the general trend of the results is still in line with the literature from across the world, suggesting possible advantages for both medicine and the economy. Transforming successful pilot programs carried out in private tertiary-care hospitals into scalable and sustainable models appropriate for public-sector district hospitals, where the burden of resistant infections is frequently highest and stewardship infrastructure is still inadequate, is a significant challenge. Even though the Indian Council of Medical Research has acknowledged the significance of antimicrobial stewardship within national policy frameworks, sufficient funding for clinical pharmacy workforce development, structured training, and stewardship resources has not yet been provided to support implementation efforts.

The educational aspect is particularly important in this regard. Several studies have documented low antimicrobial resistance awareness among prescribers in Indian hospitals, including junior doctors who make the majority of antimicrobial prescribing decisions.[38] Pharmacist delivered prescriber education has demonstrated improvements in knowledge scores, but translation of knowledge to prescribing behaviour is inconsistent without reinforcement through audit feedback and institutional accountability mechanisms. Integrating antimicrobial resistance and stewardship education into both medical and pharmacy curricula represents the most durable long-term intervention. Finally, the role of diagnostic stewardship as an enabler of antimicrobial stewardship requires greater emphasis. Pharmacist recommendations for de-escalation or cessation are dependent on the availability and timely interpretation of culture and sensitivity data; in settings where turnaround times are prolonged, the pharmacist's ability to deliver targeted stewardship is fundamentally constrained. Investment in diagnostic microbiology infrastructure is therefore a prerequisite rather than an adjunct to effective stewardship.

8. CONCLUSION

Pharmacist led antimicrobial stewardship programs are associated with improvements in prescribing appropriateness, patient safety outcomes, antimicrobial consumption, and cost efficiency across diverse international healthcare settings. The evidence is consistent in direction but heterogeneous in magnitude, and methodological limitations particularly the predominance of observational, single-centre study designs—

preclude strong causal claims. Hybrid implementation models combining prospective audit and feedback with formulary restriction appear to yield the most robust outcomes, and integration of pharmacists into multidisciplinary clinical teams is more effective than isolated pharmacy-based review.

In India, early findings from pharmacist-led antimicrobial stewardship initiatives have shown encouraging improvements in areas such as compliance with surgical prophylaxis guidelines, optimization of antimicrobial use, and enhancement of prescriber awareness and knowledge, particularly within private tertiary-care hospitals. However, the information that is now available is still methodologically restricted, and it is still unclear if it can be applied to public hospitals and healthcare settings with limited resources. The greater acceptance and efficacy of stewardship programs are nevertheless hampered by a number of enduring obstacles, including as inadequate clinical pharmacy training, hierarchical issues within healthcare teams, and limited microbiological testing facilities. Long-term and focused policy actions will be necessary to address these issues.

Strengthening pharmacist-led antimicrobial stewardship in India requires a number of significant initiatives. These include: (i) creating standardized and validated stewardship performance indicators appropriate for the Indian healthcare system; (ii) integrating thorough clinical pharmacy and antimicrobial resistance training into PharmD and undergraduate pharmacy educational programs; (iii) carrying out multicentre and controlled studies to assess stewardship effectiveness in public-sector hospitals; (iv) enhancing the infrastructure of diagnostic microbiology to facilitate targeted and evidence-based antimicrobial treatment; and (v) creating formal competence frameworks and professional standards for pharmacists engaged in antimicrobial stewardship practice. Pharmacist-led stewardship initiatives must be strengthened and expanded in order to maintain the efficacy of antibiotics for future generations as well as to improve patient care now.

DECLARATIONS

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