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Review Article

Impact of Antimicrobial Stewardship Programs on Antibiotic Prescribing Adherence: A Comprehensive Review and Prospective Evaluation Framework

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ABSTRACT

Antimicrobial resistance has increased the need for antimicrobial stewardship programs (ASPs) to improve the quality, safety, and appropriateness of antibiotic prescribing. ASPs are multidisciplinary interventions that promote evidence-based antibiotic selection, appropriate dosing, timely review, de-escalation, and discontinuation when indicated. This review summarizes the impact of stewardship strategies, including audit and feedback, formulary restriction, education, electronic decision support, and culture-guided therapy, across hospital and outpatient settings. Evidence shows that ASPs improve guideline adherence, reduce inappropriate antibiotic use, decrease unnecessary broad-spectrum prescribing, and enhance documentation of indication, duration, and intravenous-to-oral switch practices. The review also proposes a prospective framework to evaluate antibiotic prescribing patterns and guideline adherence before and after stewardship implementation. Key outcome measures include prescribing appropriateness, antibiotic consumption, culture utilization, de-escalation, and patient outcomes. Successful stewardship requires leadership support, multidisciplinary collaboration, locally adapted guidelines, continuous monitoring, and regular feedback. Integrating stewardship into routine clinical practice can optimize antibiotic use, improve patient care, and help combat the growing threat of antimicrobial resistance.

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Introduction

Antibiotics remain among the most important therapeutic resources in modern medicine, but their value is threatened when prescribing is not aligned with evidence, microbiology and patient need. In routine care, antibiotic decisions are often made under pressure, before cultures are available and in settings where clinical risk is unevenly distributed. These realities explain why overuse, underuse, overly broad empiric therapy, delayed review and unnecessarily long courses can coexist in the same health system. Antimicrobial stewardship programs respond to this complexity by converting guidelines into practical, auditable prescribing behaviours. The central question for this review is not whether guidelines exist, but whether health systems can make guideline-concordant prescribing easier, safer and more consistent at the bedside [1,2].

The topic is particularly relevant because antibiotic prescribing adherence is a measurable bridge between policy and patient care. Guidelines may recommend a first-line agent, dose, route, duration, culture strategy and review time. A stewardship program can convert these recommendations into order sets, time-outs, pharmacist review, restricted-agent approval, microbiology-linked advice and unit-level feedback. In that sense, stewardship is not only a resistance-control policy; it is also a clinical quality-improvement strategy. The evidence base shows that well-designed interventions reduce unnecessary antimicrobial exposure without compromising safety, and that the strongest programs combine enabling methods such as audit and feedback with restrictive methods where high-risk agents require oversight [3,4].

This review focuses on how stewardship interventions improve guideline compliance and how successful models from diverse healthcare systems can inform a prospective facility-level research study. The proposed research title, 'Prospective Evaluation of Antibiotic Prescribing Patterns and Guideline Adherence in a Specific Facility or Department: Impact of an Antimicrobial Stewardship Intervention,' is included because review papers are most useful when they also generate implementable methods. The framework presented here can be adapted for a medicine ward, surgery unit, intensive care unit, emergency department, outpatient clinic or specialty department depending on local burden and feasibility.

Rationale and Burden of Inappropriate Prescribing

Inappropriate antibiotic prescribing is multifactorial. It includes prescriptions given without a bacterial indication, unnecessarily broad-spectrum empiric therapy, failure to collect cultures when indicated, incorrect dose adjustment, prolonged duration after clinical stability, failure to review therapy after 48 to 72 hours and failure to document indication or stop date. These practices expose patients to adverse drug effects, Clostridioides difficile infection, drug interactions and selection pressure for resistant organisms. They also increase cost and undermine the reliability of

future empiric treatment. The global action plan on antimicrobial resistance and national stewardship frameworks therefore place antibiotic optimization at the centre of the response to resistance [5].

Guideline non-adherence does not always reflect ignorance. Prescribers may deviate because they perceive patients as unstable, because diagnostic information is incomplete, because local guidelines are not easily accessible, because senior clinicians have different habits or because the prescribing system does not prompt review. Behavioural research in stewardship has shown that prescribing is shaped by hierarchy, professional identity, fear of deterioration and expectations from patients or colleagues. A successful stewardship intervention must therefore address system design and behaviour at the same time. Education alone may improve awareness, but lasting change usually requires audit, feedback, accountability and workflow support [6].

Recent point-prevalence and prospective studies continue to show gaps in adherence, particularly in documentation, duration, culture review and use of broad-spectrum agents. Such findings support the need for local audits before intervention. A facility should not import a generic stewardship bundle without knowing where its own prescribing fails. In some departments, the main problem may be surgical prophylaxis duration; in others, it may be unrestricted use of third-generation cephalosporins, unnecessary fluoroquinolones, insufficient de-escalation, or lack of renal-dose adjustment. Baseline audit is therefore both a research tool and an implementation tool [7].

Concept and Core Elements of Antimicrobial Stewardship

Antimicrobial stewardship can be defined as coordinated interventions that promote optimal antimicrobial selection, dosing, route, duration and review. The goal is to maximize clinical cure while minimizing toxicity, resistance, unnecessary exposure and cost. The most influential frameworks identify leadership commitment, accountability, drug expertise, action, tracking, reporting and education as core elements. These elements are deliberately broad because institutions differ in size, staffing, microbiology capacity and information systems. A tertiary hospital may maintain a full infectious diseases and clinical pharmacy team, while a resource-limited facility may begin with a small multidisciplinary committee, restricted antibiotic policy and monthly audit of high-volume indications [8].

The stewardship team is ideally multidisciplinary. Physicians provide clinical authority, pharmacists contribute dosing and drug-utilization expertise, microbiologists interpret diagnostic data and resistance patterns, infection-prevention staff connect antibiotic use with transmission risk, nurses support documentation and administration timing, and administrators ensure resources and accountability. This team structure helps stewardship move beyond one-person enthusiasm. It also allows the program to influence multiple points in the prescribing pathway, from empiric selection to culture review and discharge prescription [9].

Core elements should be translated into measurable actions. Commitment can be expressed through a written policy, protected pharmacist time and leadership reporting. Accountability can be expressed through named stewardship leads and departmental review(Figure1). Drug expertise can be expressed through ward rounds, formulary advice and dosing support. Tracking can include defined daily doses, days of therapy, guideline-concordance indicators and C. difficile rates. Reporting can be done through dashboards or monthly feedback (Table1). Education should be linked to audit findings rather than delivered as isolated lectures [10].

Table 1: Core components of antimicrobial stewardship programs and their relevance to prescribing adherence

Component	Operational meaning	Expected effect on adherence	Example indicator
Leadership commitment	Administrative support, policy approval and protected time	Makes stewardship a formal clinical quality priority	Stewardship policy approved and reviewed annually
Accountability	Named clinical and pharmacy leads	Creates ownership for prescribing quality	Monthly review by stewardship committee
Drug expertise	Pharmacist, microbiologist and infectious-disease input	Improves dose, route, spectrum and de-escalation decisions	Percentage of broad-spectrum prescriptions reviewed
Action	Audit, feedback, restriction, time-out and order sets	Transforms guidelines into routine prescribing behaviour	Compliance with 48-72 hour review
Tracking	Measurement of antibiotic use and outcomes	Identifies departments and syndromes needing intervention	Days of therapy per 1000 patient-days
Reporting	Feedback to departments and leadership	Creates visibility and peer learning	Dashboard shared each month
Education	Case-based prescriber training	Improves knowledge and confidence	Attendance and pre-post knowledge scores

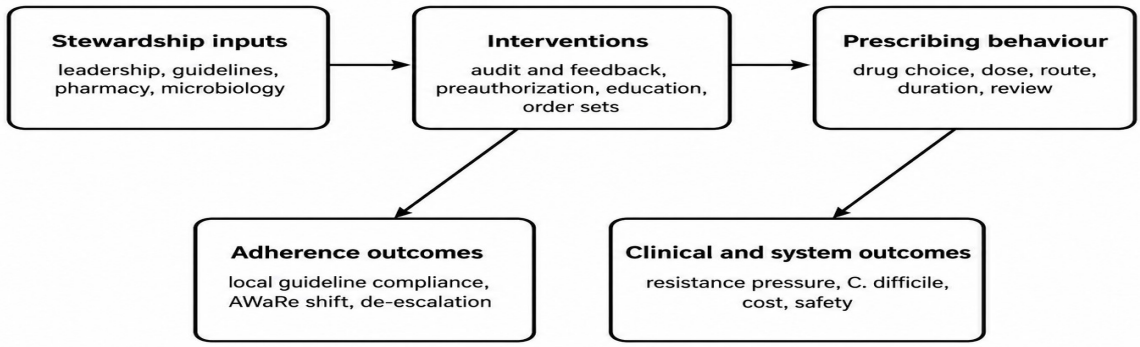

Figure 1: Conceptual pathway linking antimicrobial stewardship to prescribing adherence

Mechanisms by Which Stewardship Improves Guideline Adherence

Stewardship improves adherence first by making the correct prescribing action visible. Guidelines often fail because they are stored in long documents away from the point of care. When stewardship teams convert recommendations into pocket guides, electronic order panels, empirical therapy charts and syndrome-specific pathways, the clinician can match diagnosis to recommended therapy without searching through dense documents. This reduces variation and prevents unnecessary escalation. Visibility is especially important in high-turnover units where junior doctors rotate frequently and may not know local resistance patterns [11].

Second, stewardship improves adherence through prospective audit and feedback. In this model, prescriptions are reviewed after initiation, and prescribers receive patient-specific recommendations. Feedback can address de-escalation, discontinuation, dose correction, culture review, intravenous-to-oral switch or duration. This approach respects the initial clinical uncertainty while ensuring that therapy is revisited when more information is available. Evidence from hospital stewardship trials and systematic reviews suggests that audit and feedback is particularly useful because it teaches through real cases and preserves clinician autonomy while still creating accountability [12].

Third, stewardship improves adherence through restrictions and preauthorization. Certain agents, especially carbapenems, polymyxins, newer beta-lactam/beta-lactamase inhibitors, anti-MRSA agents and antifungals, may require approval before use. Restriction can rapidly reduce inappropriate broad-spectrum exposure, but it must be applied carefully. If the approval process is slow or punitive, prescribers may experience it as obstruction. Successful models combine restriction with accessible expert advice, urgent override pathways and review of denied requests. Restriction should protect patients and antibiotics, not simply reduce pharmacy expenditure [13].

Fourth, adherence improves when stewardship programs support diagnostic stewardship. Antibiotic decisions depend on the quality and timing of cultures, biomarkers, radiology and specimen collection. An empiric antibiotic may be guideline-concordant at initiation but become inappropriate if culture results are ignored. Stewardship programs can therefore improve specimen collection before antibiotics, discourage contaminated cultures, promote interpretation of antibiograms and standardize de-escalation when cultures identify susceptible organisms. This link between antimicrobial stewardship and microbiology is essential in hospitals where broad empiric treatment is common [14].

Fifth, stewardship improves adherence by addressing behaviour and social norms. Peer comparison, accountable justification, public commitment and senior clinician endorsement can change prescribing habits. In outpatient and emergency settings, behavioural interventions have reduced inappropriate antibiotic prescribing by making prescribers justify deviations and by comparing prescribing rates with peers. These methods work because prescribing is not purely technical; it is influenced by professional identity, patient expectations, fear and departmental norms [15].

Successful Stewardship Models Across Healthcare Systems

High-income health systems often began with hospital-based core elements and then expanded into outpatient, long-term care and emergency settings. In the United States, the CDC Core Elements framework has influenced hospital accreditation, reporting and program design. Its strength is that it provides a practical checklist rather than a narrow intervention. The United Kingdom's Start Smart Then Focus model emphasizes early appropriate empiric therapy followed by mandatory review, supporting the principle that stewardship should not delay needed antibiotics but should prevent unnecessary continuation. Both models demonstrate that adherence must be built into routine workflow rather than treated as an optional academic activity [16].

European stewardship models often integrate national action plans, surveillance networks, specialty consultation and formal training. In several countries, stewardship is linked with infection prevention and surveillance of healthcare-associated infections. Such models show the value of system-level data and multidisciplinary accountability. However, they also show that program maturity varies; even in well-resourced systems, adherence gaps persist in surgical prophylaxis duration, de-escalation and documentation. The lesson is that stewardship is not completed when a policy is written; it must be sustained through repeated measurement and feedback [17].

Resource-limited settings require adaptive models. Facilities may lack infectious diseases physicians, electronic prescribing, rapid diagnostics or pharmacist staffing. Nevertheless, stewardship can begin with feasible actions: a local antibiotic policy based on an antibiogram, restricted use of selected broad-spectrum antibiotics, monthly prescription audit, surgical prophylaxis protocols, education for interns

and residents, and simple adherence indicators. WHO AWaRe classification is particularly useful because it offers a practical way to classify antibiotic consumption and encourage Access-group use when appropriate [18].

Indian and other South Asian hospitals face high infectious disease burden, variable diagnostic access, self-medication pressures, broad-spectrum empiric prescribing and heterogeneous stewardship infrastructure. Recent facility-level studies suggest that policy-driven stewardship can improve prescribing compliance, reduce consumption and strengthen culture-guided therapy when leadership, pharmacy and microbiology are aligned. However, sustainability depends on embedding audit into the hospital's quality system rather than relying on periodic projects. The prospective research framework in this paper is designed for such settings because it uses before-and-after measurement and a bundle adaptable to local capacity [19].

Intervention Components and Evidence of Effectiveness

Education is the most visible stewardship intervention but is rarely sufficient by itself. Lectures, posters and guideline dissemination can increase awareness but may not change behaviour if prescribing workflow remains unchanged. Education works best when it is targeted to audit findings, repeated during clinical rotations, case-based and linked to senior endorsement. For example, if baseline data show excessive postoperative prophylaxis duration, education should focus on procedure-specific prophylaxis indications and stop times rather than general resistance theory. The educational message should be simple, actionable and reinforced through order sets and pharmacist review [20].

Prospective audit and feedback is one of the strongest enabling interventions (Table 2). It allows clinicians to start therapy when clinically necessary while creating a formal review point. Feedback can be delivered verbally during rounds, through written notes, electronic messages or stewardship forms. The tone of feedback matters. Recommendations framed around patient benefit and diagnostic evidence are more likely to be accepted than generic criticism. Acceptance also increases when the stewardship team is accessible and when feedback is supported by local guidelines and microbiology results [21].

Preauthorization and formulary restriction are useful for agents whose overuse can rapidly select resistance or increase cost. These strategies can improve compliance with restricted antibiotic policies, but they should not become a substitute for clinical review. A prescriber may obtain approval for empiric use, yet the prescription may still require reassessment when cultures return. Therefore, restriction is best paired with post-prescription review. Programs should monitor unintended consequences such as delays in therapy, substitution with equally broad alternatives and prescriber dissatisfaction.

Antibiotic time-outs operationalize guideline adherence by creating a formal reassessment at 48 to 72 hours. At that point, the prescriber should ask whether infection is still likely, whether cultures support the selected agent, whether the patient is clinically improving, whether the route can be changed, and what total duration is required. The time-out is powerful because it acknowledges uncertainty at initiation while preventing inertia. Many inappropriate courses continue not because someone deliberately chooses non-adherence, but because no one is prompted to stop or narrow therapy [22].

Electronic decision support can improve adherence when it is integrated into prescribing systems. Examples include indication-linked antibiotic order sets, automatic dose adjustment prompts, stop-date requirements, allergy guidance, renal function alerts and culture-result notifications. However, technology does not guarantee stewardship. Poorly designed alerts create fatigue, and rigid pathways may not fit complex patients. The best systems combine algorithmic prompts with human review and allow documentation of justified deviations from guidelines [23].

Pharmacist-led stewardship has become increasingly important. Pharmacists can review drug selection, dose, renal adjustment, interactions, therapeutic drug monitoring, duration and intravenous-to-oral switch. They are also well positioned to collect data and communicate with prescribers. Systematic reviews of pharmacist-led interventions show reductions in consumption, cost and broad-spectrum exposure, with some studies reporting improved adherence to protocols (Figure 2). The impact is greatest when pharmacists have authority, access to clinical data and regular interaction with medical teams [24].

Table 2:Common stewardship interventions and mechanisms for improving guideline compliance

Intervention	How it works	Strengths	Limitations
Prospective audit and feedback	Reviews active prescriptions and gives case-specific advice	Flexible, educational and patient-centered	Requires trained reviewers and clinician engagement
Preauthorization	Requires approval before selected restricted antibiotics are used	Rapidly limits unnecessary high-risk agents	May cause delays if poorly organized
Antibiotic time-out	Prompts review after 48-72 hours	Addresses prescribing inertia	Needs documentation and ward ownership
Local guideline dissemination	Provides syndrome-specific recommendations	Improves consistency of empiric therapy	May be ignored if not embedded in workflow
Electronic decision support	Adds prompts, order sets and stop dates	Scalable and timely	Alert fatigue and poor design can reduce effect
Pharmacist-led review	Checks dose, route, interactions and duration	Practical and accepted in many hospitals	Impact depends on pharmacist authority and access to data

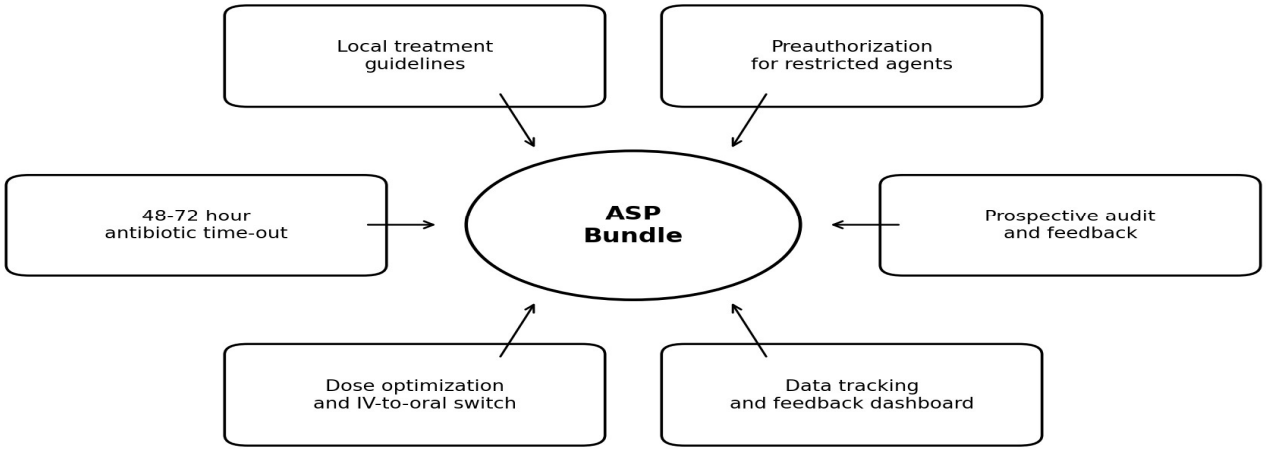

Figure 2: Multicomponent stewardship intervention bundle

Measuring Antibiotic Prescribing Adherence

Adherence should be defined before data collection begins. A simple definition such as 'guideline compliant' may be attractive, but it can hide important differences. A prescription should be evaluated across several domains: indication, agent choice, dose, frequency, route, duration, allergy consideration, culture collection, review after culture results, de-escalation and documentation. A composite adherence score can be useful, but individual domain scores are necessary for intervention design. For example, a department with high drug-choice adherence but poor duration adherence requires a different intervention from one with poor empiric selection [25].

The denominator also matters. Some studies evaluate all prescriptions; others include only encounters with infection, only antibiotics, only broad-spectrum agents or only selected syndromes such as pneumonia, urinary tract infection or surgical prophylaxis. For prospective evaluation, the denominator should be clinically meaningful and feasible. If a study is conducted in a medicine department, all adult inpatients receiving systemic antibiotics may be included. If conducted in surgery, prophylaxis and treatment prescriptions may need separate indicators because prophylaxis has different adherence domains.

Data sources include prescription charts, electronic medical records, microbiology reports, laboratory values, discharge summaries and pharmacy dispensing records. Manual audit remains common in resource-limited settings but should use a standardized form and clear adjudication rules. When adherence is uncertain, two reviewers can independently classify prescriptions and resolve disagreement by discussion. This reduces subjectivity and improves credibility. The study should also record justified deviations, because guidelines cannot cover every clinical scenario. A justified deviation is not non-adherence; it is evidence of individualized care documented appropriately.

Important quantitative measures include the proportion of prescriptions adherent to guideline agent choice, proportion with documented indication, proportion with documented stop or review date, proportion culture-guided where cultures were indicated, rate of de-escalation after culture results, proportion of Access/Watch/Reserve antibiotics, days of therapy per 1000 patient-days, defined daily doses per 1000 patient-days, average duration of therapy and acceptance of stewardship recommendations(Figure 3). Clinical balancing measures should include mortality, length of stay, treatment failure, readmission, C. difficile infection and adverse drug reactions where feasible [26].

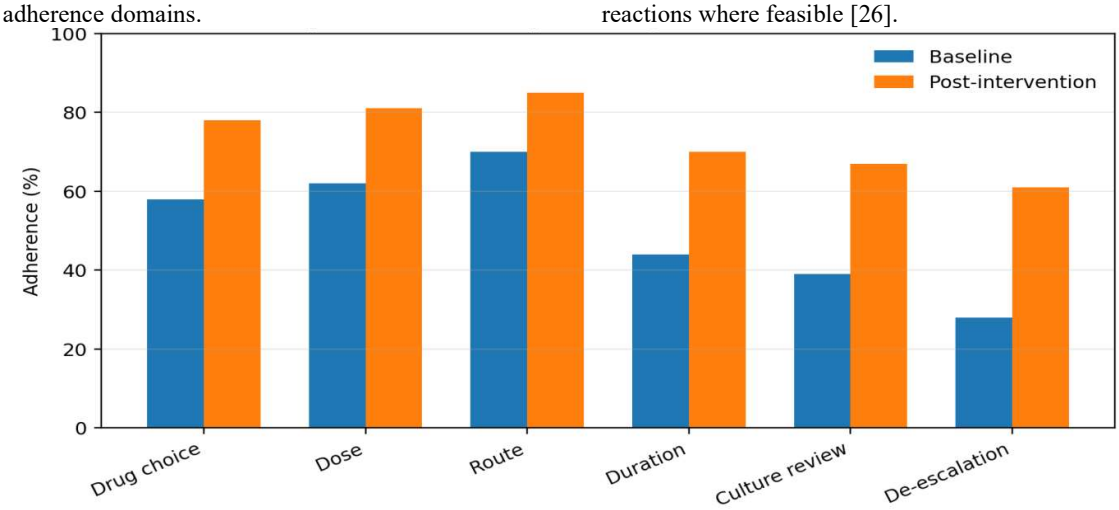

Figure 3: Illustrative prescribing adherence dashboard

Proposed Prospective Research Framework

The proposed study is titled 'Prospective Evaluation of Antibiotic Prescribing Patterns and Guideline Adherence in a Specific Facility or Department: Impact of an Antimicrobial Stewardship Intervention.' A prospective before-and-after design is suitable when the objective is to measure routine prescribing patterns, implement an intervention and compare post-intervention adherence. Although randomized designs provide stronger causal inference, many hospitals implement stewardship as a quality-improvement necessity, making randomization difficult. A well-designed prospective audit with clear criteria, adequate sample size, consistent data collection and balancing outcomes can still provide useful evidence for local practice[27].

The study population may include all eligible patients admitted to the selected facility or department who receive at least one systemic antibiotic during the audit period. Inclusion criteria should specify age group, department, inpatient or outpatient status and minimum prescription information required. Exclusion criteria may include incomplete records, patients transferred out before assessment, topical antimicrobials alone, anti-tubercular or antiretroviral therapy if outside the study scope, and patients enrolled in another conflicting protocol. The final criteria should match the facility's clinical context and ethical approvals[28].

The baseline phase should measure current practice without influencing prescribers beyond routine care. Data collection should capture demographics, diagnosis, comorbidities, indication for antibiotic, empirical or definitive therapy, culture collection, antibiotic name, class, AWaRe category, dose, route, frequency, start date, review date, stop date, guideline recommendation and adherence domains(Table 3). This phase identifies the most common antibiotics, high-burden diagnoses and non-adherence patterns. It also provides a baseline for calculating change after intervention[29].

The intervention phase should be targeted and feasible. A practical bundle may include dissemination of a locally adapted antibiotic guideline, prescriber education, antibiotic time-out form, pharmacist review of selected broad-spectrum agents, culture-review prompt and monthly feedback dashboard. The intervention should focus on a limited number of high-yield behaviours rather than attempting to change every prescribing decision at once. For example, if baseline data show low culture utilization and prolonged duration, the bundle should prioritize culture-before-antibiotic reminders and stop-date documentation(Figure 4)[30].

The post-intervention phase should use the same data collection tool and adherence definitions as baseline. This consistency is critical. If criteria change after intervention, measured improvement may reflect measurement change rather than practice change. The primary outcome can be overall guideline adherence or composite adherence across predefined domains. Secondary outcomes can include culture-guided therapy, de-escalation rate, average duration, broad-spectrum use, AWaRe category distribution, documented indication, stop date, acceptance of stewardship recommendations and antibiotic consumption indicators[31].

Statistical analysis should include descriptive statistics for prescribing patterns and comparative analysis between baseline and post-intervention phases. Categorical outcomes such as adherence proportions can be compared using chi-square or Fisher's exact tests. Continuous outcomes such as duration or days of therapy can be compared using t tests or non-parametric alternatives depending on distribution. Multivariable logistic regression may identify predictors of adherence, such as department, diagnosis, empirical therapy, culture availability, senior review and restricted antibiotic use. Interrupted time-series analysis can be considered when monthly data are available over longer periods [32].

Table 3: Proposed variables for prospective evaluation of antibiotic prescribing patterns

Variable domain	Examples of variables	Purpose in analysis	Data source
Patient profile	Age, sex, ward, comorbidity, renal function	Describes case mix and risk factors	Medical record
Clinical indication	Diagnosis, infection site, severity, empirical/definitive therapy	Links antibiotic choice to guideline pathway	Case sheet and progress notes
Prescription details	Antibiotic, class, AWaRe group, dose, route, frequency, duration	Measures antibiotic use and appropriateness	Drug chart/pharmacy record
Microbiology	Culture sent, organism, susceptibility, timing	Assesses culture-guided therapy and de-escalation	Laboratory reports
Adherence domains	Drug choice, dose, route, duration, review, documentation	Primary and secondary outcomes	Audit tool
Outcomes	Clinical improvement, length of stay, adverse reaction, escalation, readmission	Balancing and patient-safety measures	Medical record/discharge summary

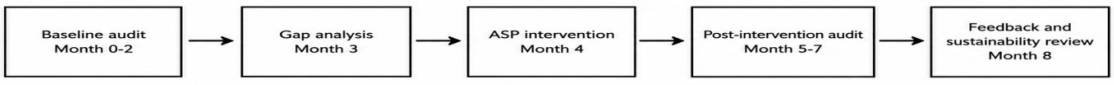

Figure 4: Prospective before and after study design for evaluating prescribing adherence

Ethical, Operational and Implementation Considerations

A prospective stewardship evaluation usually involves review of routine clinical records and implementation of a quality-improvement intervention. Nevertheless, ethics approval is important because patient data are collected and prescribing behaviour is evaluated. The protocol should describe confidentiality, data storage, de-identification, consent approach and the fact that stewardship recommendations do not replace clinical judgment. If the intervention includes direct prescriber feedback, the program should be framed as patient-safety improvement rather than punitive surveillance. This framing improves acceptability and reduces defensive prescribing[33].

Operational feasibility is a major determinant of success. A program that requires daily infectious diseases review may not be feasible in a hospital without such staffing. A realistic intervention may rely on a clinical pharmacist, microbiology liaison and department champion. Data collection should be simple enough to sustain beyond the research period. If the audit form is too long, accuracy may decline and the program may stop once the study ends(Table 4). The best stewardship research produces a data system that the facility can continue using[34].

Leadership support is essential. Without administrative backing, stewardship recommendations may remain optional and data may not reach decision-makers. Leadership can support protected time, reporting structures, guideline approval, pharmacy formulary control and information-system changes. Departmental champions are equally important because prescribing behaviour is often shaped by local norms. A respected physician champion can normalize guideline adherence and reduce the perception that stewardship is external policing [35].

Implementation should also consider unintended consequences. Overemphasis on reducing antibiotic use could create fear of undertreatment, especially in sepsis or immunocompromised patients. Stewardship must distinguish between appropriate early empiric therapy and unnecessary continuation. Balancing measures such as treatment failure, escalation, readmission and mortality help reassure clinicians that improved adherence does not compromise safety.Published meta-analyses generally support the safety of stewardship, but each facility should monitor its own outcomes [36].

Table 4: Suggested outcome indicators for facility-level stewardship evaluation

Outcome type	Indicator	Definition	Interpretation
Primary process outcome	Overall guideline adherence	Prescription meets all predefined essential criteria or has justified deviation	Direct measure of prescribing quality
Secondary process outcome	Documented indication and stop/review date	Percentage of antibiotic orders with both elements recorded	Measures prescribing visibility and accountability
Diagnostic outcome	Culture utilization before antibiotics	Eligible cases with appropriate specimen collected before therapy	Reflects diagnostic stewardship
Optimization outcome	De-escalation rate	Eligible cases narrowed or stopped after culture/clinical review	Reflects active review and reduced unnecessary spectrum
Consumption outcome	Days of therapy per 1000 patient-days	Total antibiotic exposure standardized by patient-days	Monitors volume of use
Balancing outcome	Treatment failure or escalation	Clinical deterioration requiring escalation or antibiotic broadening	Checks patient safety during stewardship

Challenges and Barrier

One major barrier is diagnostic uncertainty. Clinicians may continue broad-spectrum therapy because they are unsure whether infection is present or because cultures are negative after antibiotics have already begun. Stewardship programs should not simply demand narrowing; they should improve diagnostic pathways and provide decision support for stopping therapy when infection becomes unlikely. Negative cultures, clinical stability and alternative diagnoses should trigger review rather than automatic continuation[37].

Another barrier is hierarchical prescribing. Junior clinicians may write antibiotic orders but feel unable to change therapy without senior approval. In such settings, education directed only at interns will have limited effect. Stewardship must engage senior consultants, residents, nurses and pharmacists together. Department-level feedback can show variation without blaming individuals, and case discussions can demonstrate safe de-escalation. Culture change is gradual and requires repeated reinforcement [38].

Limited microbiology capacity is a frequent challenge in resource-constrained settings. If cultures are unavailable, delayed or costly, prescribers rely heavily on empirical therapy. Stewardship can still improve adherence by using local antibiograms, syndrome-specific guidance, review of clinical response and AWaRe classification. However, long-term improvement requires investment in laboratory capacity and timely reporting. Stewardship and diagnostics should be developed together, not as separateprograms[39].

Data quality can also limit evaluation. Prescriptions may lack indication, planned duration or documented review. This absence itself is an adherence problem, but it also makes classification difficult. A stewardship intervention should therefore require documentation as a first step. Documenting indication and duration does not guarantee correct therapy,

but it makes prescribing visible and reviewable. Visibility is the foundation of improvement [40].

Opportunities for Future Stewardship Models

The future of stewardship lies in learning health systems that connect prescribing, diagnostics, outcomes and resistance patterns. Rather than relying only on periodic audits, hospitals can develop real-time dashboards that identify broad-spectrum starts, missing stop dates, prolonged courses, culture mismatches and opportunities for intravenous-to-oral switch. Such systems should be designed to support clinicians, not overwhelm them with alerts. Human stewardship expertise remains necessary to interpret complex cases and negotiate behaviour change.

The WHO AWaRe framework offers a practical opportunity for facilities that lack advanced analytics. By classifying antibiotics as Access, Watch or Reserve, programs can monitor whether prescribing shifts toward safer first-line agents when clinically appropriate. AWaRe-based indicators are not a substitute for diagnosis-specific guidelines, but they provide a useful high-level stewardship signal. Facilities can combine AWaRe monitoring with local adherence audits to understand both quantity and quality of antibiotic use.

Another opportunity is embedding stewardship into undergraduate, postgraduate and continuing medical education. Prescribing habits begin early. If junior clinicians learn to document indication, collect cultures, review at 48 hours and choose guideline-concordant therapy from the beginning, stewardship becomes part of routine professionalism. Simulation, case-based teaching and ward-based feedback may be more effective than theoretical lectures alone.

Equity should also be included in future stewardship. Facilities serving low-income populations may face barriers such as delayed presentation, limited diagnostics and affordability constraints. Stewardship should not become a mechanism for denying treatment; rather, it should ensure that patients receive the right antibiotic when needed and avoid harm when not needed. In resource-limited contexts, stewardship must be paired with access to essential antibiotics, diagnostics and infection prevention(Figure 5) [32].

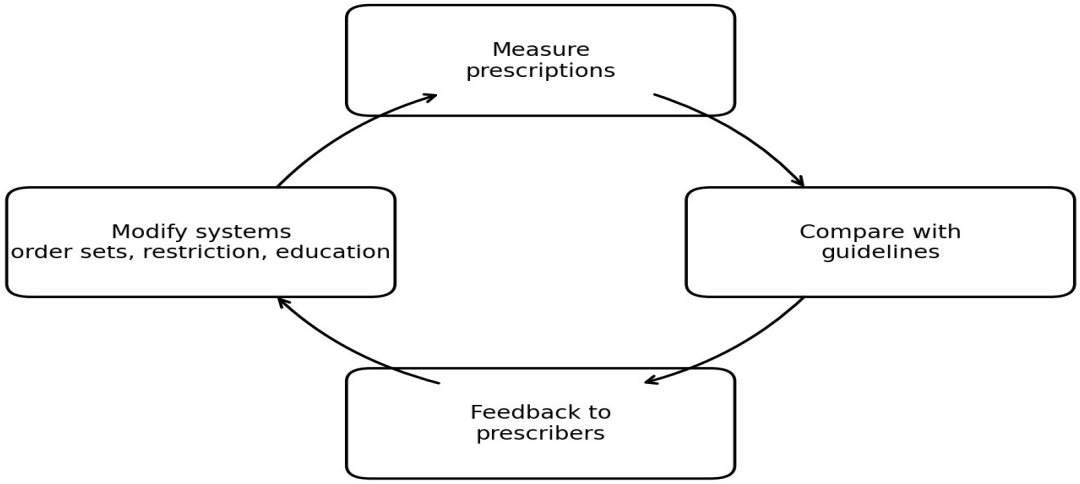

Figure 5: Continuous quality improvement cycle for stewardship adherence

Discussion

The evidence reviewed in this paper supports the conclusion that antimicrobial stewardship programs improve antibiotic prescribing adherence when they are structured, multidisciplinary and locally adapted. The most effective programs do not rely on one intervention. They combine clear guidelines, audit and feedback, preauthorization for selected agents, antibiotic time-outs, diagnostic support, education, measurement and leadership accountability. These components target different causes of non-adherence: lack of knowledge, lack of access to guidelines, clinical uncertainty, prescribing inertia, social norms and system-level absence of review.

A key insight is that adherence should be interpreted as a multi-dimensional outcome. A prescription may be correct in drug choice but incorrect in dose or duration. Another may be non-guideline but clinically justified because of allergy, culture history or severe immunosuppression. Therefore, the proposed prospective study should not classify prescriptions mechanically. It should apply transparent criteria and allow documented justified deviations. This approach respects clinical judgment while still identifying avoidable variation.

The proposed research framework is practical for facilities seeking to evaluate and improve their own antibiotic use. It begins with baseline audit, uses findings to design a targeted intervention, measures post-intervention change and includes balancing outcomes. It can be applied to a general medicine ward, surgical department, intensive care unit or outpatient setting with modifications. The most important requirement is consistency of data collection and institutional commitment to act on findings.

The main limitation of stewardship evidence is heterogeneity. Studies vary in design, setting, intervention, outcome definitions and follow-up. Some report antibiotic consumption, others adherence, cost, resistance, C. difficile infection or mortality. This makes direct comparison difficult. However, the direction of evidence is consistent: stewardship can reduce inappropriate use and improve quality without compromising patient safety when implemented responsibly. Future studies should report both

process and patient outcomes, include longer follow-up and describe contextual factors that affect implementation.

Conclusion

Antimicrobial stewardship programs are essential for improving adherence to antibiotic prescribing guidelines through evidence-based interventions, continuous monitoring, multidisciplinary collaboration, and integration into routine clinical practice. Effective stewardship should be tailored to individual departments, supported by sustainable leadership, regular audit and feedback, meaningful quality indicators, patient education, and close coordination with infection prevention programs. Evaluation should consider both guideline adherence and clinical outcomes to ensure appropriate antibiotic use and patient safety. Future research should continue assessing stewardship interventions and disseminate findings to support continuous quality improvement, optimize antibiotic use, and reduce antimicrobial resistance.

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