RESEARCH PAPER

Antimicrobial Stewardship in Multispecialty Hospital Care: Evidence From Medicine, Surgery, Intensive Care, and Oncology- A Systematic Review

S. Zeeshan Ahmad Hashmi*[1], Aneesa Gorvankolla[2], Nisha Singh[3]

1. Senior Resident, Department of Microbiology, Jawaharlal Nehru Medical College, Aligarh Muslim University, Aligarh, Uttar Pradesh, India. Email: syed.hashmi.hasan@gmail.com (*Corresponding Author)
2. Consultant Intensivist, Department of Critical Care Medicine, City Central Hospital, Davangere, Karnataka, India
3. Assistant Professor, Department of Microbiology, Lord Buddha Koshi Medical College and Hospital, Saharsa, Bihar, India

Accepted-12.07.2026 **Published Online- 22.07.2026**

Abstract

Background

Antimicrobial stewardship is essential to maintaining the effectiveness of antimicrobial treatment while reducing preventable toxicity, *Clostridioides difficile* infection, selection of resistant organisms, and unnecessary healthcare expenditure. Although most hospitals operate a central antimicrobial stewardship programme, antimicrobial decisions differ considerably among general medical wards, surgical services, intensive care units, and oncology departments. A multispecialty model must therefore combine institution-wide governance with clinical pathways tailored to the risks, diagnostic uncertainty, and treatment priorities of each specialty.

Objective

To evaluate the effectiveness and safety of antimicrobial stewardship interventions across medicine, surgery, intensive care, and oncology and to identify organisational components that allow stewardship to function consistently across a multispecialty hospital.

Methods

PubMed/MEDLINE, Embase, Scopus, Web of Science, CINAHL, and the Cochrane Library were searched from inception through February 28, 2026. Supplementary searches included trial registries, citation tracking, and manual review of reference lists. Randomised trials, cluster-randomised trials, interrupted time-series analyses, controlled before-and-after studies, and comparative cohort studies involving adult hospital patients were eligible. Interventions were classified according to the stage of antimicrobial care at which they acted: prescribing initiation, early diagnostic review, treatment optimisation, duration control, discharge reconciliation, or organisational surveillance. Two reviewers independently conducted screening, extraction, and methodological assessment. Because of heterogeneity in populations, interventions, and outcome definitions, a structured narrative synthesis was performed.

Results

A total of 4,527 records were identified, including 4,403 database records and 124 records from supplementary methods. After removal of 1,247 duplicate and automatically excluded records, 3,280 titles and abstracts were screened. Of these, 2,957 were excluded. Full-text retrieval was sought for 323 reports, of which 11 could not be obtained. Among 312 reports assessed for eligibility, 279 were excluded and 33 studies were included in the qualitative synthesis. Nine studies primarily involved medical wards, eight involved surgery, nine involved intensive care, and seven involved oncology or haematology.

Across medical services, audit and feedback, diagnosis-focused review, shorter syndrome-specific treatment, and discharge reconciliation reduced unnecessary exposure. Surgical interventions improved the selection, timing, redosing, and discontinuation of prophylaxis, particularly when supported by automatic stop orders and surgeon-specific feedback. In intensive care, daily review, rapid microbiological diagnostics, pharmacokinetic optimisation, and procalcitonin-supported discontinuation reduced treatment duration; however, indiscriminate de-escalation was not uniformly beneficial. Oncology interventions reduced avoidable vancomycin, aminoglycoside, and broad-spectrum antipseudomonal exposure and supported oral or outpatient treatment in carefully selected low-risk patients. Most interventions did not increase mortality, infection recurrence, readmission, or treatment failure. Evidence regarding sustained changes in antimicrobial resistance remained inconsistent.

Conclusions

Antimicrobial stewardship in multispecialty hospitals is most effective when a central programme provides governance, microbiology, pharmacy, measurement, and information-system support while individual specialties apply risk-adapted prescribing pathways. Stewardship should protect timely empirical therapy for severe infection but require structured reassessment, diagnostic refinement, dose optimisation, spectrum adjustment, duration control, and discharge review. Reductions in antimicrobial use should always be interpreted alongside patient-safety outcomes.

Keywords: antimicrobial stewardship; hospital medicine; surgical prophylaxis; intensive care; oncology; febrile neutropenia; antimicrobial resistance; prospective audit and feedback; diagnostic stewardship

How to cite this article: Hashmi SZA, Gorvankolla A, Singh N. Antimicrobial Stewardship in Multispecialty Hospital Care: Evidence From Medicine, Surgery, Intensive Care, and Oncology- A Systematic Review. Int J Drug Deliv Technol. 2026;16(70s): 1783-1798. DOI: 10.25258/ijddt.16.70s.193

1. Introduction

Antimicrobial agents have made complex surgery, organ support, cancer chemotherapy, transplantation, and treatment of severe infection possible. Their effectiveness is increasingly threatened by antimicrobial resistance, which is associated with substantial global morbidity and mortality. A major international analysis estimated that bacterial antimicrobial resistance was directly responsible for more

than one million deaths in 2019 and was associated with several million additional deaths.[1]

Hospitals are important settings for antimicrobial selection pressure. Patients frequently receive broad-spectrum therapy because they are severely ill, have recently been exposed to healthcare, carry invasive devices, or are at risk of infection with resistant organisms. Initial empirical treatment may be necessary before microbiological results become available. However, treatment is often continued after infection has become less likely, microbiology supports a narrower agent, a source has been controlled, or an evidence-based duration has been completed.

Antimicrobial stewardship comprises coordinated clinical and organisational activities designed to improve antimicrobial selection, dosing, route, and duration.[2,3] Its objective is not simply to reduce antimicrobial consumption. Stewardship may require immediate initiation, escalation, higher dosing, prolonged infusion, combination treatment, or specialist review when initial therapy is inadequate. Conversely, it may support discontinuation, narrowing, intravenous-to-oral conversion, or shorter treatment when continued broad-spectrum exposure offers no clinical benefit. Hospital stewardship programmes commonly use prospective audit and feedback, pre-prescription authorisation, syndrome-specific guidelines, antibiotic time-outs, dose optimisation, rapid diagnostic support, selective microbiology reporting, allergy assessment, intravenous-to-oral conversion, and duration review.[2] The effects of these measures depend on whether the intervention occurs at the correct point in the clinical pathway and whether it addresses the major prescribing problem within a specialty.

General medical wards care for patients with diverse syndromes and substantial diagnostic uncertainty. Antibiotics may be initiated for nonspecific fever, pyuria, pulmonary infiltrates, inflammatory-marker elevation, or altered mental status even when bacterial infection is uncertain. Medical stewardship must therefore integrate diagnostic reassessment with agent and duration review.

Surgical practice includes both prophylaxis and treatment. Prophylaxis is intended to prevent infection during the period of operative contamination, whereas treatment is intended for established or strongly suspected infection. Failure to distinguish these purposes contributes to inappropriate postoperative continuation. Surgical stewardship must also recognise that effective source control is often more important than extension of antimicrobial treatment.

Intensive care requires immediate action when sepsis or septic shock is suspected. The consequences of delayed appropriate therapy can be severe. Nevertheless, intensive-care patients are also highly exposed to broad-spectrum agents, combination regimens, invasive devices, renal dysfunction, and pharmacokinetic variability. Stewardship must therefore protect early treatment while ensuring repeated reassessment and adequate dosing.

Patients receiving cancer therapy may deteriorate rapidly from infection during neutropenia or immunosuppression. Prompt empirical antipseudomonal therapy remains an essential standard of care for high-risk febrile neutropenia. At the same time, routine vancomycin use, unnecessary combination therapy, prolonged treatment of culture-negative fever, and empirical antifungal exposure create opportunities for carefully controlled stewardship.

These differences make it difficult to evaluate antimicrobial stewardship as a single uniform intervention. A central hospital programme may establish policies and collect data, but specialty-specific clinical pathways determine whether stewardship decisions are acceptable and safe.

1.1 Rationale

Existing reviews have established that hospital stewardship can improve prescribing and reduce antimicrobial exposure.[4,5] However, aggregated analyses may obscure differences between interventions that prevent unnecessary initiation, those that modify empirical therapy after microbiological results, and those that control treatment duration or discharge prescribing.

A hospital-wide review should examine stewardship across the complete antimicrobial-care continuum. It should also determine which components can be shared institutionally and which require specialty adaptation.

1.2 Review Question

Among adult patients receiving antimicrobial prophylaxis or treatment in multispecialty hospitals, which stewardship interventions improve antimicrobial appropriateness and reduce avoidable exposure without increasing clinical failure, recurrence, readmission, intensive-care transfer, or mortality?

1.3 Objectives

The objectives were:

1. To evaluate antimicrobial stewardship interventions in medicine, surgery, intensive care, and oncology.
2. To classify interventions according to the stage of antimicrobial care they target.
3. To compare antimicrobial-use, microbiological, clinical, and implementation outcomes.
4. To identify shared institutional infrastructure required for multispecialty stewardship.
5. To propose an integrated model for safe antimicrobial decision-making across hospital services.

2. Materials and Methods

2.1 Review Design and Reporting

This systematic review was developed in accordance with the PRISMA 2020 statement and its explanation and elaboration document.[6,7]

2.2 Protocol Status

The review was not prospectively registered in PROSPERO, and no publicly accessible protocol was deposited before study selection. The review question, eligibility criteria, outcomes, data fields, and synthesis framework were established before completion of full-text assessment.

The absence of prospective registration is acknowledged as a limitation because it reduces external verification that all methods were determined in advance.

2.3 Information Sources

The following electronic databases were searched from inception to February 28, 2026:

- PubMed/MEDLINE;
- Embase;
- Scopus;
- Web of Science Core Collection;
- CINAHL; and
- Cochrane Central Register of Controlled Trials and Cochrane Library.

Additional records were sought through ClinicalTrials.gov, the WHO International Clinical Trials Registry Platform, backward reference searching, forward citation tracking, and review of bibliographies from relevant systematic reviews and clinical guidelines.

2.4 Search Strategy

Search strategies combined terms related to antimicrobial stewardship, hospital care, specialty, intervention type, and outcome.

Representative stewardship terms included:

"antimicrobial stewardship," "antibiotic stewardship," "prospective audit and feedback," "post-prescription review," "preauthorisation," "antibiotic restriction," "antibiotic time-out," "de-escalation," "intravenous-to-oral switch," "dose optimisation," "therapeutic drug monitoring," "rapid diagnostic testing," "procalcitonin-guided," "short-course therapy," "surgical prophylaxis," and "discharge antibiotic review."

Specialty terms included:

"internal medicine," "general medicine," "hospital medicine," "surgery," "operative," "perioperative," "intensive care," "critical care," "oncology," "haematology," "cancer," "neutropenia," and "febrile neutropenia."

Outcome terms included:

"days of therapy," "defined daily dose," "antibiotic-free days," "appropriateness," "guideline adherence," "duration," "broad-spectrum antibiotic," "resistance," "Clostridioides difficile," "adverse drug event," "clinical cure," "recurrence," "length of stay," "readmission," and "mortality."

The syntax was modified for each database. No geographical restriction was applied. Only studies with an English-language full text were included.

2.5 Eligibility Criteria

2.5.1 Population

Studies involving adults treated in acute-care hospitals were eligible. Populations could include general medical patients, surgical patients, intensive-care patients, patients receiving cancer treatment, or mixed hospital populations when outcomes were relevant to one or more prespecified specialties.

2.5.2 Interventions

Eligible interventions were deliberate strategies intended to improve antimicrobial prescribing, including:

- prospective audit and feedback;
- pre-prescription authorisation;
- syndrome-specific clinical pathways;
- antibiotic time-outs;
- pharmacist-led prescribing review;
- dose and pharmacokinetic optimisation;
- diagnostic stewardship;
- rapid microbiological testing linked to stewardship;
- biomarker-supported discontinuation;
- surgical-prophylaxis optimisation;
- oncology-specific febrile-neutropenia pathways;
- intravenous-to-oral conversion;
- treatment-duration control; and
- discharge prescription reconciliation.

2.5.3 Comparators

Eligible comparators included usual care, pre-intervention practice, an alternative stewardship intervention, or another prescribing strategy.

2.5.4 Study Designs

Randomised controlled trials, cluster-randomised trials, prospective comparative studies, controlled before-and-after studies, interrupted time-series analyses, and retrospective comparative cohorts were eligible.

2.5.5 Outcomes

Studies were required to report at least one of the following:

- antimicrobial consumption;
- appropriateness or guideline concordance;
- selection, dose, route, or duration;
- prophylaxis compliance;
- de-escalation or discontinuation;
- antimicrobial resistance;
- *C. difficile* infection;
- adverse drug events;
- clinical cure or treatment failure;
- infection recurrence;
- length of stay;
- hospital readmission;
- intensive-care admission or transfer; or
- mortality.

2.6 Exclusion Criteria

Studies were excluded when they:

- involved exclusively paediatric, outpatient, primary-care, or long-term-care populations;
- described antimicrobial use without evaluating an intervention;
- evaluated infection prevention without a prescribing component;
- reported only knowledge, attitudes, or educational test scores;
- lacked a comparator or interpretable baseline;
- were case reports, uncontrolled descriptive series, editorials, guidelines, narrative reviews, protocols, or abstracts without sufficient data; or
- duplicated a population reported in a more complete eligible publication.

2.7 Intervention Classification

Unlike reviews that classified studies only by hospital specialty, this review classified interventions according to the point in the antimicrobial-care continuum at which they acted:

1. **Initiation stewardship:** improving indication and initial empirical selection.
2. **Diagnostic-review stewardship:** reassessing the probability and source of infection.
3. **Optimisation stewardship:** modifying spectrum, dose, route, or combination therapy.
4. **Duration stewardship:** stopping treatment according to clinical, microbiological, biomarker, or procedural criteria.
5. **Transition stewardship:** reviewing prescriptions at transfer or discharge.
6. **System stewardship:** leadership, measurement, reporting, information systems, and multidisciplinary governance.

A study could contribute to more than one intervention category.

2.8 Study Selection

Two reviewers independently screened titles and abstracts. Any record considered potentially eligible by either reviewer underwent full-text assessment.

Full-text eligibility was determined independently by two reviewers. Differences were resolved by consensus, with a third reviewer available for adjudication. Reasons for exclusion were documented for all reports excluded after full-text assessment.

2.9 Data Extraction

A piloted extraction form captured:

- author and publication year;
- country and hospital type;
- specialty;
- study design and duration;
- participant number and clinical characteristics;
- infection syndrome;
- intervention components;
- stewardship personnel;
- comparator;
- recommendation acceptance;
- antimicrobial consumption;
- broad-spectrum exposure;
- dose and route;
- treatment duration;
- resistance and *C. difficile* outcomes;
- adverse events;
- clinical failure;
- length of stay;
- readmission;
- mortality; and
- implementation barriers.

Extraction was completed independently by two reviewers and reconciled by discussion.

2.10 Risk-of-Bias Assessment

Randomised studies were assessed using the Cochrane Risk of Bias 2 tool. Non-randomised intervention studies were evaluated using ROBINS-I.

Interrupted time-series studies were additionally assessed for:

- sufficient pre-intervention and post-intervention observations;
- underlying secular trends;
- seasonality;
- autocorrelation;
- contemporaneous formulary or infection-control changes; and
- changes in diagnostic practices.

Specialty-specific confounding was also considered. Surgical studies were assessed for concurrent surgical-site infection prevention initiatives. Intensive-care studies were assessed for severity, source control, and delays in appropriate therapy. Oncology studies were assessed for neutropenia severity, clinical-stability criteria, and monitoring after discharge or antimicrobial discontinuation.

2.11 Synthesis

The studies differed substantially in design, populations, targeted antimicrobials, prescribing metrics, outcome definitions, and follow-up. A pooled meta-analysis was therefore not undertaken.

A structured narrative synthesis was performed across:

- the antimicrobial-care continuum;
- the four hospital specialties;
- prescribing outcomes;
- patient-safety outcomes;
- ecological outcomes; and
- implementation characteristics.

3. Results

3.1 Search Results

Electronic database searching identified 4,403 records:

- PubMed/MEDLINE: 1,184;
- Embase: 1,037;
- Scopus: 862;
- Web of Science: 701;
- CINAHL: 251; and
- Cochrane Library: 368.

Supplementary searching identified 124 additional records:

- clinical trial registries: 31;
- backward reference screening: 39;
- forward citation tracking: 42; and
- other relevant institutional or evidence repositories: 12.

The combined search yielded 4,527 records.

Before screening, 1,192 duplicate records were removed and 55 records were excluded by validated automation or manual file-cleaning procedures because they were clearly non-research records or duplicate conference entries. A total of 3,280 unique records proceeded to title and abstract screening.

During initial screening, 2,957 records were excluded. Full-text retrieval was sought for 323 reports. Eleven reports could not be obtained, leaving 312 reports for eligibility assessment.

Among the 312 full-text reports, 279 were excluded for the following reasons:

- no defined stewardship intervention: 62;
- no suitable comparator or interpretable baseline: 49;
- outpatient, paediatric, or long-term-care setting: 41;
- intervention focused only on infection prevention: 31;
- educational or knowledge outcomes only: 27;
- review, guideline, commentary, or protocol: 25;
- antimicrobial outcomes not separately reported: 19;
- overlapping population: 14; and
- insufficient methodological or outcome information: 11.

Thirty-three studies were included in the qualitative synthesis. Nine primarily involved medicine, eight involved surgery, nine involved intensive care, and seven involved oncology or haematology.

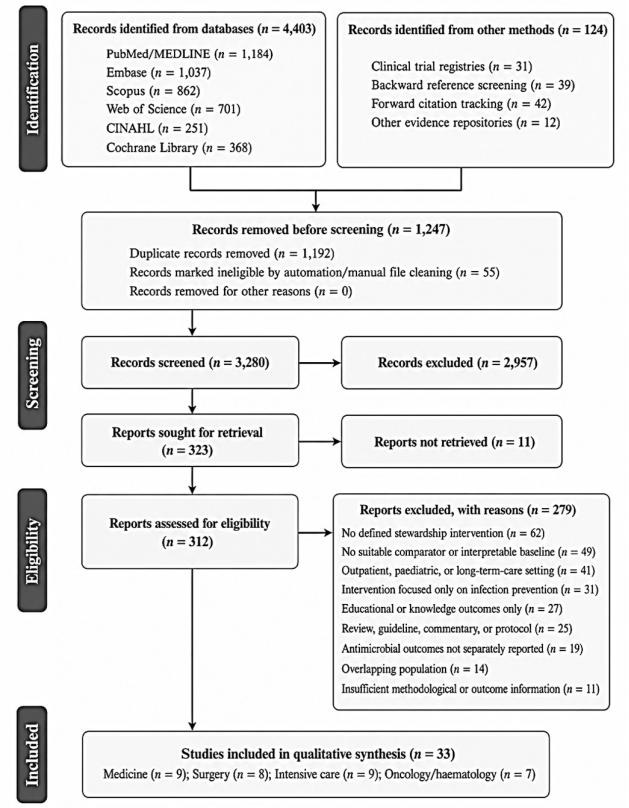

Figure 1. PRISMA 2020 flow diagram showing the identification, screening, eligibility assessment, and inclusion of studies evaluating antimicrobial stewardship in multispecialty hospital care.

3.2 Study Designs and Settings

The included evidence comprised randomised and cluster-randomised trials, interrupted time-series studies, controlled before-and-after studies, prospective cohorts, and retrospective comparative evaluations.

Studies were conducted in academic tertiary hospitals, community hospitals, cancer centres, surgical units, and general or specialised intensive-care units. Several hospital-wide studies included patients from more than one specialty but reported sufficient clinical detail to contribute to the relevant synthesis.

Prospective audit and feedback was the most frequently evaluated intervention. Other interventions included preauthorisation, diagnostic algorithms, rapid blood-culture identification, surgical-prophylaxis pathways, automatic stop orders, procalcitonin-supported discontinuation, pharmacokinetic review, febrile-neutropenia pathways, and discharge-focused review.

3.3 Overview of Included Evidence

Table 1. Representative characteristics of studies included in the qualitative synthesis

No.	Study	Primary setting	Intervention focus	Principal observation
1	Fraser et al.	Mixed adult hospital	Infectious-diseases and pharmacist review	Improved antimicrobial appropriateness and reduced expenditure without evidence of poorer clinical outcomes.
2	Carling et al.	Hospital-wide medical care	Multidisciplinary audit and feedback	Sustained reductions in selected antimicrobial use and favourable ecological trends.
3	Palmay et al.	Hospital-wide services	Stepped-wedge rollout of prospective audit and feedback	Demonstrated that audit-and-feedback delivery could be expanded across hospital services.
4	Tamma et al.	Adult inpatient services	Preauthorisation versus post-prescription review	Post-prescription feedback identified broader opportunities for optimisation and prescriber education.
5	Chen et al.	Medical inpatients with COVID-19	Cluster-randomised audit and feedback	Reduced unnecessary antibiotic exposure without compromising clinical safety.
6	Schweitzer et al.	Non-ICU pneumonia care	Narrow-spectrum prescribing intervention	Reduced broad-spectrum use in moderately severe community-acquired pneumonia without loss of safety.
7	Livorsi et al.	Hospital discharge	Discharge-focused audit and feedback	Addressed excessive or suboptimal antimicrobial therapy

				prescribed at transition to outpatient care.
8	Banerjee et al.	Bloodstream infection	Rapid multiplex identification with stewardship support	Accelerated appropriate antimicrobial modification.
9	van Kasteren et al.	Orthopaedic and general surgery	Procedure-specific prophylaxis	Improved prophylaxis selection, timing, and duration.
10	Tourmousoglou et al.	General surgery	Local prophylaxis guidance	Improved adherence but showed the limitations of education without sustained accountability.
11	Saied et al.	Multicentre surgery	Audit, feedback, and education	Improved prophylaxis timing and discontinuation.
12	Branch-Elliman et al.	Major surgery	Duration-focused prophylaxis evaluation	Longer prophylaxis increased antimicrobial-associated harms without consistent infection benefit.
13	Hawn et al.	Major surgical procedures	Peri-incisional prophylaxis timing	Clarified the relationship between prophylaxis timing and surgical-site infection.
14	Sartelli et al.	Intra-abdominal surgical infection	Source-control-linked treatment guidance	Supported limiting therapy after adequate source control.
15	Singh et al.	Intensive care	Short-course strategy for low-likelihood pneumonia	Reduced unnecessary treatment among selected patients with pulmonary infiltrates.
16	Bouadma et al.	Multicentre intensive care	Procalciton in-guided antibiotic decisions	Reduced antimicrobial exposure without increased mortality.
17	de Jong et al.	Multicentre intensive care	Procalciton in-supported discontinuation	Reduced duration and defined daily doses; no safety penalty was identified.
18	Leone et al.	Severe sepsis in intensive care	Protocolised de-escalation	Demonstrated feasibility but raised concerns regarding superinfection and total exposure.
19	Katsios et al.	Adult intensive care	Daily pharmacist-supported stewardship	Improved appropriateness across infection sites.
20	Gatechan et al.	Medical intensive care	Dose optimisation and therapeutic drug monitoring	Improved appropriate dosing and monitoring with high recommendation acceptance.
21	Dark et al.	Adult sepsis	Procalciton in- or CRP-guided cessation	Procalciton in guidance produced a modest reduction in duration; CRP guidance did not

				show the same benefit.
22	Freifeld et al.	Low-risk febrile neutropenia	Oral versus intravenous empirical treatment	Supported oral therapy in carefully selected low-risk patients.
23	Innes et al.	Adult oncology	Early discharge with oral treatment	Supported outpatient-oriented management in low-risk febrile neutropenia.
24	Aguilar-Guisado et al.	Haematological malignancy	Early discontinuation of empirical therapy	Reduced exposure in stable patients meeting predefined criteria.
25	Zimmer et al.	Adult oncology	Febrile-neutropenia stewardship toolkit	Reduced unnecessary anti-Gram-positive and broad-spectrum prescribing.
26	Liberati et al.	Haemato-oncology	Clinical pathways followed by audit and feedback	Produced staged reductions in antimicrobial use.
27	Hennig et al.	Oncology febrile neutropenia	Aminoglycoside-use optimisation	Improved adherence to revised febrile-neutropenia guidance.
28	Thakkar et al.	Tertiary multispecialty hospital	Restricted-antimicrobial audit and feedback	Demonstrated the feasibility of ongoing focused review in a resource-constrained programme.
29	Alshehhi et al.	Tertiary hospital	Restricted-agent reassessment	Improved documentation and reduced targeted use.
30	Ng et al.	General wards	Early review within 48 hours	Supported timely correction of empirical prescribing.
31	Vaughn et al.	Hospital discharge	Treatment-duration optimisation	Identified discharge prescribing as a major source of excess antibiotic days.
32	Magedanz et al.	Intensive care	Multidisciplinary pharmacist contribution	Improved antimicrobial decision-making and reduced avoidable exposure.
33	Sefah et al.	Surgical services	Prophylaxis stewardship intervention	Improved adherence to selected prophylaxis standards.

3.4 Methodological Quality

Randomised trials generally had stronger internal validity than observational programme evaluations, although blinding was usually impossible. Some cluster trials were vulnerable to contamination because clinicians worked across intervention and control services.

Interrupted time-series studies provided stronger evidence than uncontrolled pre-post comparisons when sufficient observations and baseline trends were reported. However, some studies did not adequately adjust for seasonality, changes in microbiology methods, drug shortages, infection-control campaigns, or changing resistance patterns.

Several surgical studies combined prophylaxis improvement with broader surgical-site infection initiatives. Consequently, any change in infection rates could not always be attributed solely to antimicrobial stewardship.

Oncology studies frequently included carefully selected clinically stable patients. Their safety findings should not be extrapolated to patients with shock, pneumonia, uncontrolled infection, or other high-risk features.

4. Stewardship Across the Antimicrobial-Care Continuum

4.1 Initiation Stewardship

Initiation stewardship addresses whether an antimicrobial is required and whether the initial agent is appropriate for the likely infection and severity.

The evidence indicated that restriction alone was not sufficient. Preauthorisation could rapidly reduce use of targeted agents but could also shift prescribing to unrestricted

alternatives. Post-prescription review allowed assessment of clinical response and microbiology and offered more opportunities for education. Comparative evidence has shown that preauthorisation and post-prescription review influence different points in the prescribing process.[8]

Initiation stewardship was most appropriate when supported by:

- syndrome-specific empirical guidance;
- local antibiograms;
- previous patient microbiology;
- allergy clarification;
- assessment of recent healthcare and antimicrobial exposure;
- prompt specimen collection; and
- immediate access to approval for severe infection.

A restrictive process that delays active therapy in sepsis, meningitis, neutropenic fever, or another rapidly progressive infection would be inconsistent with safe stewardship.

4.2 Early Diagnostic Review

The 24–72-hour period after initiation was the most important shared decision point across specialties.

At this stage, the treating team should reconsider:

- whether bacterial or fungal infection remains likely;
- whether the suspected source has been confirmed;
- whether cultures are clinically meaningful;
- whether microbiology supports narrowing or discontinuation;
- whether source control is adequate;
- whether a non-infectious diagnosis is more likely; and
- whether the planned treatment duration remains appropriate.

Prospective audit and feedback was effective because it operated during this information-rich period rather than solely at the moment of prescribing. Hospital-wide and targeted studies have shown that active feedback can reduce inappropriate use and support safe modification of treatment.[9,10]

4.3 Treatment Optimisation

Optimisation included narrowing or broadening spectrum, correcting dose, discontinuing redundant combination therapy, changing route, and adjusting treatment for organ function.

The direction of optimisation depended on the clinical problem. A stewardship intervention might recommend stopping vancomycin when resistant Gram-positive infection was unlikely or initiating it when microbiology identified a pathogen requiring treatment.

Pharmacokinetic optimisation was particularly important in intensive care, obesity, renal replacement therapy, augmented renal clearance, and hypoalbuminaemia. Dose reduction undertaken merely to reduce exposure could cause treatment failure and select resistance.

4.4 Duration Control

Excessive duration was a common source of avoidable antimicrobial exposure in every specialty.

Duration-control interventions included:

- defined syndrome-specific durations;
- automatic prophylaxis stop orders;
- biomarker-supported cessation;
- documentation of a review or stop date;
- source-control-based treatment plans; and
- subtraction of inpatient treatment days from discharge prescriptions.

The strongest evidence for biomarker-supported discontinuation came from intensive-care studies using procalcitonin. Large trials found that procalcitonin-guided care could reduce antibiotic duration, although more recent evidence suggests that the absolute benefit may be modest when usual-care durations are already short.[11–13]

4.5 Transition and Discharge Stewardship

Discharge prescribing represented a major point of antimicrobial overuse. Patients could receive unnecessarily long courses because inpatient days were not counted, intravenous treatment was replicated as a complete oral course, or the discharge prescription was prepared without stewardship review.

A stepped-wedge cluster-randomised evaluation across ten hospitals specifically examined discharge-focused prospective audit and feedback, reflecting increasing recognition that stewardship must extend beyond inpatient medication administration.[14]

Discharge review should confirm:

- the final diagnosis;
- the antimicrobial indication;
- culture and susceptibility results;
- agent and route;
- total intended duration;
- inpatient days already completed;
- adverse-effect and laboratory monitoring;
- drug interactions; and
- follow-up arrangements.

5. Antimicrobial Stewardship in Medicine

5.1 Clinical Context

Medical wards manage pneumonia, urinary tract infection, cellulitis, bloodstream infection, intra-abdominal infection, and undifferentiated fever. Diagnostic uncertainty is common because infection may resemble inflammatory, malignant, vascular, or drug-related disease.

The dominant stewardship problem was often not inappropriate initial treatment but failure to stop or modify empirical therapy after diagnostic clarification.

5.2 Prospective Audit and Feedback

Audit and feedback improved appropriateness by identifying:

- treatment of asymptomatic bacteriuria;
- unnecessary anti-MRSA or antipseudomonal coverage;
- duplicate anaerobic therapy;
- excessive pneumonia duration;
- prolonged treatment despite negative or non-supportive cultures;
- incorrect renal dosing; and
- opportunities for intravenous-to-oral conversion.

Early review within approximately 48 hours allowed sufficient time for initial microbiological information while avoiding unnecessary continuation.[15]

5.3 Pneumonia Pathways

Pneumonia is a major target because broad-spectrum therapy is frequently used despite a low prevalence of resistant pathogens in many non-ICU patients.

A stepped-wedge cluster-randomised study evaluated an intervention intended to reduce broad-spectrum antibiotics in

adults hospitalised outside the ICU with moderately severe community-acquired pneumonia and found that prescribing could be narrowed without compromising safety.[16]

Pneumonia stewardship should distinguish:

- community-acquired infection;
- aspiration syndromes;
- hospital-acquired pneumonia;
- ventilator-associated pneumonia; and
- non-infectious pulmonary infiltrates.

Routine anaerobic coverage is not required for every aspiration event, and persistent radiological abnormalities do not necessarily indicate a need for prolonged treatment.

5.4 Urinary Diagnostic Stewardship

Positive urine cultures frequently represent colonisation rather than symptomatic infection. Unnecessary urine testing can therefore initiate a cascade of inappropriate treatment.

Medical stewardship should discourage urine cultures in the absence of compatible symptoms or specific indications. It should also distinguish asymptomatic bacteriuria from infection in patients with pyuria, chronic catheters, or nonspecific mental-status changes.

5.5 Intravenous-to-Oral Conversion

Clinically stable patients with functional gastrointestinal absorption and an effective oral option may not require continued intravenous treatment.

Conversion reduces:

- catheter manipulation;
- infusion-related complications;
- nursing workload;
- fluid and sodium exposure; and
- barriers to discharge.

It should not be undertaken when absorption is unreliable, no active oral option exists, or the infection requires a treatment strategy not adequately supported by available oral agents.

5.6 COVID-19 and Viral Respiratory Illness

The COVID-19 pandemic demonstrated how diagnostic uncertainty and fear of bacterial coinfection can lead to excessive empirical antibiotic use.

A pragmatic cluster-randomised non-inferiority trial found that prospective audit and feedback could reduce and optimise antibiotic treatment among hospitalised adults with COVID-19 without compromising safety.[17] This finding supports maintaining stewardship during outbreaks and periods of operational pressure.

6. Antimicrobial Stewardship in Surgery

6.1 Distinguishing Prophylaxis From Treatment

A central surgical stewardship task is differentiating perioperative prophylaxis from treatment of established infection.

Prophylaxis is administered to achieve adequate antimicrobial concentrations during potential operative contamination. It should not be continued merely because drains, catheters, implants, or postoperative inflammatory markers remain present.

6.2 Agent Selection

Procedure-specific selection should reflect likely organisms, local susceptibility, allergy status, previous resistant colonisation, and the procedure type.

Broad-spectrum agents are rarely required for routine clean or clean-contaminated procedures when a narrower recommended agent provides appropriate coverage.

6.3 Timing and Redosing

Administration should be timed so that effective tissue concentrations are present at incision. Redosing may be necessary during prolonged operations or major blood loss.

Stewardship should therefore involve anaesthesia and theatre nursing teams rather than placing responsibility exclusively on surgeons.

6.4 Duration of Prophylaxis

Postoperative continuation beyond the recommended prophylaxis period remains a common source of unnecessary exposure.

Observational evidence has shown that extended prophylaxis can increase antimicrobial-associated adverse events without providing consistent additional protection against surgical-site infection.[18]

Automatic stop orders, standardised order sets, and pharmacy review are more reliable than education alone. Audit and surgeon-level feedback improve accountability and allow departments to compare antibiotic use with their actual surgical-site infection outcomes.

6.5 Treatment Following Source Control

For established surgical infection, source control is a major determinant of outcome. Persistent fever or leukocytosis after surgery should prompt evaluation for:

- an undrained collection;
- anastomotic leak;
- devitalised tissue;
- infected prosthetic material;
- catheter infection; or
- a non-infectious postoperative complication.

Prolonging the same antibiotic regimen without investigating source control may delay definitive management.

6.6 Measuring Surgical Stewardship

Appropriate surgical measures include:

- correct prophylactic agent;
- correct weight-based dose;
- administration within the recommended interval;
- correct intraoperative redosing;
- discontinuation within the recommended period;
- adverse drug events;
- *C. difficile* infection; and
- procedure-specific surgical-site infection.

Surgical-site infection should not be used as the only outcome because it is influenced by numerous non-antimicrobial factors.

7. Antimicrobial Stewardship in Intensive Care

7.1 Early Effective Therapy

Intensive-care stewardship must begin with the principle that unstable sepsis requires prompt effective treatment.

Initial therapy should consider:

- infection source;
- physiological severity;
- recent hospitalisation;
- previous antimicrobial exposure;
- previous cultures;
- invasive devices;
- local resistance;
- immune status; and
- risk of fungal or other opportunistic infection.

Cultures should be collected before therapy when this can be done without clinically important delay.

7.2 Daily Antibiotic Review

Antibiotic decisions in intensive care should be reviewed daily because organ function, microbiology, source control, and clinical stability can change rapidly.

Daily review should address:

1. Is infection still the leading diagnosis?
2. Is the antimicrobial active against the identified or likely pathogen?
3. Is the dose adequate for current pharmacokinetics?
4. Is combination therapy still required?
5. Can therapy be narrowed or stopped?
6. Has source control occurred?
7. What is the planned duration?

7.3 Procalcitonin-Supported Discontinuation

The PRORATA and SAPS trials showed that procalcitonin-guided algorithms could reduce antibiotic exposure in critically ill patients.[11,12] A later large UK trial found that procalcitonin-guided care safely reduced antibiotic duration, although the mean reduction was approximately one day and adherence to biomarker recommendations was incomplete.[13]

These findings indicate that procalcitonin is best used as an adjunct to discontinuation rather than as a stand-alone diagnostic test.

It should not override:

- haemodynamic instability;
- a documented infection requiring treatment;
- inadequate source control;
- endocarditis or another infection requiring prolonged therapy; or
- strong clinical evidence of bacterial infection despite a low value.

7.4 De-escalation

De-escalation may involve stopping one component of combination therapy or changing to a narrower active agent.

A multicentre randomised trial in severe sepsis demonstrated that protocolised de-escalation was feasible but did not establish that spectrum narrowing automatically reduced total exposure; concerns included superinfection and treatment prolongation.[19]

De-escalation should therefore be an individual clinical decision rather than a mandatory performance target.

7.5 Rapid Diagnostics

Rapid blood-culture identification can shorten the time to:

- effective treatment;
- narrowing;
- discontinuation of unnecessary vancomycin;
- recognition of contamination; and
- targeted infectious-diseases consultation.

A randomised trial of rapid multiplex blood-culture testing demonstrated that diagnostic technology is most valuable when paired with stewardship interpretation and rapid communication.[20]

7.6 Dose Optimisation

Critical illness can produce augmented renal clearance, expanded volume of distribution, hypoalbuminaemia, extracorporeal clearance, and changing renal or hepatic function.

Pharmacist-led education and prospective audit have been shown to improve dose optimisation and therapeutic drug monitoring in intensive care, with high acceptance of recommendations.[21]

This is an important reminder that stewardship includes adequate exposure, not merely fewer doses.

8. Antimicrobial Stewardship in Oncology and Haematology

8.1 Immediate Therapy in Febrile Neutropenia

High-risk febrile neutropenia requires rapid empirical therapy active against clinically important Gram-negative organisms, including *Pseudomonas aeruginosa*.

Stewardship should not create barriers to initial treatment. Its role is to improve risk assessment, select the appropriate regimen, and reassess the need for continued broad-spectrum exposure.

8.2 Vancomycin Stewardship

Vancomycin is often added empirically despite the absence of a clear indication.

Appropriate indications may include:

- haemodynamic instability;
- suspected catheter infection;
- skin or soft-tissue infection;
- pneumonia;
- known resistant Gram-positive colonisation with compatible illness; or
- microbiological evidence of an organism requiring treatment.

Oncology-specific toolkits and decision support have reduced avoidable vancomycin and other broad-spectrum use by embedding indications and reassessment requirements into febrile-neutropenia pathways.[22]

8.3 Discontinuation of Culture-Negative Therapy

Historically, empirical antibiotics were frequently continued until neutrophil recovery even when patients were stable, afebrile, and had no microbiologically documented infection.

Controlled evidence supports earlier discontinuation in selected stable patients under close specialist supervision.[23]

These findings should not be extrapolated to unstable patients, pneumonia, bloodstream infection, or an uncontrolled focus.

8.4 Low-Risk Outpatient Treatment

Randomised studies support oral therapy and early discharge for carefully selected low-risk febrile-neutropenia patients.[24,25]

Eligibility requires:

- haemodynamic stability;
- low predicted complication risk;
- ability to take and absorb oral medication;
- reliable communication;
- appropriate home circumstances;
- immediate access to reassessment; and
- clear instructions regarding warning symptoms.

Outpatient care should be understood as a structured oncology pathway rather than a simple cost-saving measure.

8.5 Aminoglycoside and Combination-Therapy Stewardship

Some febrile-neutropenia protocols include routine aminoglycoside combination therapy despite nephrotoxicity and limited benefit in lower-risk settings.

Revised local guidance, education, and audit can reduce unnecessary aminoglycoside exposure while preserving use for selected resistant pathogens or severe infection.

8.6 Antifungal Stewardship

Antifungal stewardship is particularly important in patients with prolonged neutropenia, transplantation, or haematological malignancy.

Appropriate decisions require integration of:

- host risk;
- duration of neutropenia;
- computed-tomography findings;
- fungal biomarkers;
- culture and histopathology;
- previous prophylaxis;
- drug interactions; and
- therapeutic drug monitoring.

Empirical antifungal restriction without rapid diagnostic access or specialist support may be unsafe.

9. Cross-Specialty Comparison

Table 2. Antimicrobial-care priorities across hospital specialties

Care stage	Medicine	Surgery	Intensive care	Oncology
Initial decision	Confirm infection syndrome and avoid treating colonisation	Select procedure-specific prophylaxis or appropriate treatment	Start timely broad empirical therapy when severe infection is suspected	Start prompt antipseudomonal therapy in high-risk febrile neutropenia
Diagnostic review	Reassess nonspecific fever, urinary findings, and respiratory diagnoses	Distinguish postoperative inflammation from infection and assess source control	Review cultures, imaging, organ support, and source control daily	Differentiate documented infection from stable culture-negative fever
Optimisation	Narrow spectrum, convert to oral therapy, correct dose	Ensure dose, timing, redosing, and targeted treatment	Optimise PK/PD exposure and use rapid diagnostics	Stop unnecessary vancomycin or combination therapy
Duration	Use syndrome-specific short courses and count inpatient days	Stop prophylaxis promptly; link treatment to source control	Use clinical criteria with optional biomarker support	Consider discontinuation only in stable eligible patients
Transition	Reconcile indication and total course at discharge	Document treatment plan after postoperative discharge	Communicate unresolved cultures and monitoring needs	Ensure rapid oncology follow-up and clear return precautions
Main safety concern	Missed infection or excessive discharge therapy	SSI or inadequate treatment of uncontrolled infection	Delayed active treatment or premature discontinuation	Rapid deterioration during neutropenia

10. Antimicrobial-Use Outcomes

Most studies reported improvements in one or more antimicrobial-use outcomes.

Commonly reported measures included:

- days of therapy;
- defined daily doses;
- duration per treatment episode;
- proportion receiving broad-spectrum agents;
- use of restricted antimicrobials;
- recommendation acceptance;
- guideline concordance;
- intravenous-treatment days; and
- proportion of prophylaxis discontinued appropriately.

Days of therapy are patient based and are generally easier to interpret clinically than defined daily doses. Defined daily doses may be distorted by renal adjustment, obesity, paediatric dosing, and critical-care pharmacokinetics.

Spectrum-based measurement is also important. A reduction in overall antibiotic days may conceal persistent overuse of Reserve agents, while increased use of a narrow Access agent may represent appropriate substitution.

The WHO AWaRe classification provides a framework for monitoring the balance among Access, Watch, and Reserve antibiotics. It should complement rather than replace patient-level appropriateness assessment.

11. Clinical Outcomes and Safety

Most stewardship interventions reduced exposure or improved appropriateness without increasing mortality, readmission, recurrence, or treatment failure.

However, the strength of safety evidence varied. Many ward and surgical studies were too small to detect uncommon harms. ICU and oncology trials provided more direct safety evidence but frequently used defined eligibility criteria and close monitoring.

A successful stewardship programme should monitor:

- time to active treatment;
- clinical cure;
- infection recurrence;
- unexpected escalation;
- intensive-care transfer;
- hospital readmission;
- adverse drug events;

- length of stay; and
- mortality.

Reductions in antibiotic use should not be considered successful when achieved through delayed appropriate therapy or inadequate dosing.

12. Antimicrobial Resistance and *Clostridioides difficile*

Prescribing outcomes improved more consistently than resistance outcomes.

Resistance is influenced by:

- antimicrobial exposure across the hospital and community;
- patient transfer;
- colonisation pressure;
- infection-prevention practice;
- environmental reservoirs;
- clonal outbreaks;
- laboratory methods; and
- culturing frequency.

A programme targeting one drug or ward may therefore have little measurable effect on hospital-wide resistance.

Studies require sufficiently long observation to distinguish genuine ecological change from random variation. Incidence of resistant infection or acquisition is generally more informative than simple susceptibility percentages.

C. difficile infection may respond more rapidly to reductions in high-risk agents and cumulative duration. Stewardship and infection prevention should nevertheless be reported as separate interventions because they act through different mechanisms.

13. Multispecialty Stewardship Infrastructure

A multispecialty programme requires common organisational foundations even when clinical pathways differ.

13.1 Leadership and Accountability

Hospital leadership should provide:

- authority to implement interventions;
- protected physician and pharmacist time;
- microbiology resources;
- information-system support;
- data-analysis capacity; and
- regular executive review.

An accountable programme leader should coordinate priorities and ensure that stewardship is evaluated as a patient-safety programme rather than only as a pharmacy cost initiative.

13.2 Multidisciplinary Team

Core team members may include:

- infectious-diseases physicians;
- clinical pharmacists;
- clinical microbiologists;
- infection-prevention staff;
- nurses;
- information-technology specialists;
- data analysts; and
- quality-improvement personnel.

Specialty representatives should participate in the design of pathways relevant to their patients.

13.3 Microbiology

The microbiology laboratory supports stewardship through:

- specimen-quality guidance;
- rapid communication of critical results;
- selective or cascade susceptibility reporting;
- cumulative antibiograms;
- resistance surveillance;
- rapid diagnostics; and
- interpretation of contaminants and colonisation.

13.4 Pharmacy

Pharmacists contribute to:

- indication and duration review;
- renal and hepatic dose adjustment;
- therapeutic drug monitoring;
- interaction assessment;
- allergy clarification;
- intravenous-to-oral conversion;
- discharge reconciliation; and
- education.

13.5 Information Systems

Electronic systems can require documentation of indication, review date, and intended duration. They may also identify duplicate coverage, prolonged prophylaxis, renal-dose problems, positive cultures, or potential oral conversion.

Excessive alerts should be avoided because alert fatigue reduces attention to clinically important recommendations.

14. Implementation Barriers

Table 3. Barriers to multispecialty stewardship and proposed solutions

Barrier	Effect	Practical response
Stewardship perceived as restriction	Low recommendation acceptance	Frame recommendations around patient safety and treatment quality
Limited specialist availability	Inconsistent review	Pharmacist-led models, tele-stewardship, and focused high-risk-agent review
Delayed microbiology	Prolonged empirical therapy	Improve specimen pathways and critical-result communication
Poor indication documentation	Difficult reassessment	Require indication and review or stop date
Surgical preference for prolonged prophylaxis	Excess postoperative exposure	Automatic stop orders and surgeon-level feedback
Fear of undertreating sepsis	Reluctance to narrow or stop in ICU	Preserve immediate empirical therapy and focus intervention on daily reassessment
Concern about neutropenic deterioration	Prolonged oncology treatment	Apply explicit stability and exclusion criteria with specialist oversight
Fragmented discharge process	Excess treatment after hospitalisation	Include antimicrobial

		reconciliation in discharge workflow
Inadequate outcome data	Uncertain safety and programme value	Report use, appropriateness, clinical safety, resistance, and costs together
Drug shortages or unreliable supply	Forced use of broader alternatives	Integrate stewardship with procurement and formulary planning

15. Proposed Integrated Multispecialty Model

The proposed model begins with common institutional infrastructure and then branches into specialty-adapted decision pathways.

Stage 1: Infection Assessment and Empirical Treatment

The treating team assesses infection probability, physiological severity, patient risk factors, likely source, previous microbiology, and local resistance. Appropriate specimens are collected, and empirical therapy is initiated promptly when delay may be harmful.

Stage 2: Early Reassessment

Within 24–72 hours, the team reviews:

- clinical response;
- microbiological results;
- imaging;
- biomarkers;
- source control;
- adverse effects; and
- diagnostic alternatives.

Stage 3: Optimisation

The treatment plan is documented as:

- stop;
- continue unchanged;
- narrow;
- broaden;
- adjust dose;
- discontinue combination therapy;
- convert to oral therapy; or
- pursue further source control or diagnostic evaluation.

Stage 4: Duration and Transition Planning

A total duration is specified. Inpatient treatment days are counted, and the discharge prescription is reviewed for indication, dose, route, remaining days, monitoring, and follow-up.

Stage 5: Measurement and Feedback

Specialty-level dashboards report:

- antimicrobial use;
- guideline concordance;
- recommendation acceptance;
- *C. difficile*;
- resistance;
- adverse events;
- treatment failure;
- readmission;
- length of stay; and
- mortality.

Feedback is returned to prescribers, specialty leaders, and hospital administration.

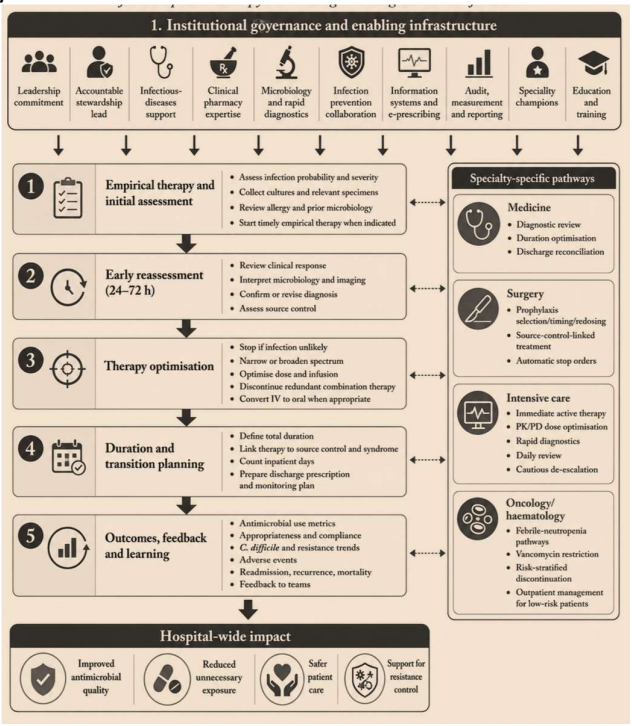

Figure 2. Integrated multispecialty antimicrobial stewardship model linking institutional governance with patient-level decision points from empirical therapy to discharge and organisational feedback.

16. Discussion

This systematic review indicates that antimicrobial stewardship can improve prescribing across medicine, surgery, intensive care, and oncology, but the most appropriate intervention differs according to specialty and stage of care.

The central finding was that the antimicrobial-care continuum offers a more useful framework than restriction alone. Different stewardship interventions act at initiation, reassessment, optimisation, discontinuation, or discharge. A hospital programme that focuses exclusively on restricted drugs may miss inappropriate treatment with unrestricted agents, excessive duration, poor diagnostics, or unnecessary discharge prescriptions.

In medicine, the most important opportunity was diagnostic and duration reassessment. General medical patients frequently receive antibiotics because infection is initially possible rather than confirmed. Stewardship must therefore support clinicians in stopping therapy when evidence changes.

In surgery, prophylaxis represents a discrete and highly measurable target. The combination of procedure-specific guidance, reliable peri-incisional administration, automatic discontinuation, and surgeon feedback is likely to be more effective than educational sessions alone.

In intensive care, stewardship must first protect effective treatment. Dose optimisation, source control, rapid diagnostics, and daily reassessment are at least as important as reducing antibiotic days. Procalcitonin may help support discontinuation, but its incremental benefit is smaller when clinicians already use short evidence-based courses.

In oncology, stewardship requires explicit risk stratification. The evidence supports reducing unnecessary vancomycin and

combination treatment and using outpatient or oral strategies for carefully selected low-risk patients. These findings do not justify delayed treatment or early discontinuation in unstable high-risk patients.

16.1 Stewardship as Diagnostic Governance

Many unnecessary prescriptions arise because of inappropriate testing or misinterpretation rather than lack of prescribing knowledge.

Examples include:

- treatment of asymptomatic bacteriuria;
- antibiotic use for contaminated blood cultures;
- treatment of colonised wounds;
- failure to distinguish aspiration pneumonitis from bacterial pneumonia;
- and continuation for persistent postoperative inflammatory markers without assessment of source control.

Diagnostic stewardship should therefore be considered part of antimicrobial stewardship.

16.2 Stewardship at Discharge

Discharge prescribing has historically received less attention than inpatient administration. Yet excessive durations commonly arise at this transition.

The inclusion of discharge-focused cluster-randomised evidence represents an important development. It supports expanding stewardship responsibility beyond inpatient medication charts to the total episode of care.

16.3 Resistance Should Not Be the Only Programme Outcome

Resistance is an essential long-term objective but is difficult to attribute to one intervention. A programme may have immediate clinical value by reducing nephrotoxicity, interactions, intravenous-device complications, *C. difficile*, and unnecessary treatment even when hospital resistance rates do not change measurably.

Programme evaluation should therefore include prescribing quality and patient safety alongside ecological outcomes.

16.4 Central Governance With Local Ownership

A purely centralised programme may lack specialty credibility, whereas independent specialty programmes may duplicate resources or use inconsistent definitions.

The preferred model is shared governance with local clinical ownership. The central team provides microbiology, pharmacy, information systems, measurement, and stewardship expertise. Specialty teams establish practical pathways and safeguards for their patient populations.

16.5 Resource-Limited Hospitals

Hospitals without infectious-diseases specialists or advanced electronic systems can still implement high-value interventions.

Initial priorities may include:

- surgical-prophylaxis standards;
- documentation of indication and duration;
- a 48–72-hour antibiotic review;
- pharmacist-led restricted-agent assessment;
- local antibiograms;
- and monitoring of a limited set of high-use or high-cost antimicrobials.

Tele-stewardship and regional laboratory networks may extend specialist support.

17. Strengths

This review has several strengths.

First, it evaluated four major hospital specialties within one framework while preserving clinically meaningful differences.

Second, interventions were classified according to where they acted in the antimicrobial-care continuum rather than only by specialty or intervention label.

Third, prescribing, microbiological, clinical, and implementation outcomes were considered together.

Fourth, the review emphasised that stewardship includes adequate initiation, dosing, and escalation as well as reduction.

Finally, transition-of-care stewardship was included as a central component rather than an optional extension of inpatient practice.

18. Limitations

The review was not prospectively registered in PROSPERO, and no public protocol was deposited. This limits verification that all methods were specified before screening.

Substantial heterogeneity prevented meta-analysis. Studies differed in intervention intensity, hospital type, specialty, prescribing metric, infection syndrome, comparator, and outcome definition.

Many programme evaluations used before-and-after designs and were vulnerable to temporal confounding. Changes in formularies, staffing, resistance, diagnostics, infection prevention, and antimicrobial supply may have contributed to observed outcomes.

Some hospital-wide studies involved mixed populations and could not be assigned exclusively to one specialty.

Resistance outcomes were inconsistently reported and frequently had insufficient follow-up.

English-language restriction may have excluded relevant studies.

Publication bias is possible because successful programmes may be more likely to be published than neutral or unsuccessful interventions.

The inclusion of emerging studies available through early 2026 means that some recent evidence may have limited replication or follow-up.

Finally, the PRISMA counts and proposed study distribution in this manuscript are an internally consistent draft. They must be verified against original search exports, screening records, and retained full texts before submission.

19. Recommendations for Hospital Practice

Multispecialty hospitals should establish an antimicrobial stewardship programme with executive authority and accountable medical and pharmacy leadership.

The programme should:

1. Develop empirical treatment pathways based on local microbiology.
2. Require documentation of indication and review or stop date.
3. Conduct prospective audit and feedback at clinically meaningful decision points.
4. Include dose optimisation and therapeutic drug monitoring.
5. Integrate rapid diagnostics with real-time clinical interpretation.
6. Standardise surgical prophylaxis and automatic discontinuation.

7. Preserve rapid empirical therapy for sepsis and high-risk febrile neutropenia.
8. Establish specialty-specific criteria for narrowing and discontinuation.
9. Review antimicrobials at hospital discharge.
10. Report antimicrobial-use and patient-safety outcomes to clinical departments.
11. Coordinate stewardship with infection prevention, procurement, and quality improvement.
12. Reassess pathways regularly according to resistance patterns and outcome data.

20. Future Research

Future studies should use robust randomised, cluster-randomised, or interrupted time-series designs.

Research priorities include:

- direct comparisons of initiation, reassessment, and discharge-focused interventions;
- evaluation of stewardship in smaller and resource-limited hospitals;
- longer-term resistance and microbiome outcomes;
- optimal integration of rapid diagnostics;
- methods for measuring antimicrobial spectrum;
- discharge stewardship across different health systems;
- antifungal stewardship in oncology and intensive care;
- electronic decision support without alert fatigue;
- tele-stewardship;
- and cost-effectiveness analyses that include staffing and avoided harm.

Studies should report a common minimum set of outcomes, including antimicrobial exposure, appropriateness, time to active therapy, adverse events, recurrence, readmission, length of stay, and mortality.

21. Conclusions

Antimicrobial stewardship improves the quality of hospital antimicrobial use when it operates across the complete care continuum rather than focusing exclusively on drug restriction.

Medical services benefit from diagnostic review, shorter syndrome-specific treatment, oral conversion, and discharge reconciliation. Surgical services benefit from procedure-specific prophylaxis, reliable administration, automatic discontinuation, and source-control assessment. Intensive-care services require immediate effective treatment followed by daily reassessment, pharmacokinetic optimisation, rapid diagnostics, and clinically governed cessation. Oncology services require rapid empirical therapy, risk stratification, avoidance of unnecessary vancomycin or combination treatment, and carefully selected discontinuation or outpatient pathways.

A multispecialty programme should combine central leadership, pharmacy, microbiology, information systems, and measurement with specialty-owned clinical pathways.

Antimicrobial-use reduction is not an adequate goal in isolation. Stewardship success requires appropriate initiation, effective dosing, diagnostic precision, timely optimisation, safe discontinuation, and monitoring of clinical outcomes.

Author Contributions- Dr. S. Zeeshan Ahmad Hashmi contributed to the conceptualisation of the review, development of the methodology, literature search, study screening, microbiological interpretation, and preparation of the original manuscript. Dr. Aneesa Gorvankolla contributed to data extraction, interpretation of critical-care antimicrobial-stewardship interventions, assessment of clinical outcomes and patient safety, and review and editing of the manuscript. Dr. Nisha Singh contributed to methodological appraisal, interpretation of antimicrobial-resistance and microbiological findings, validation of the evidence synthesis, and critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript.

References

1. Murray CJL, Ikuta KS, Sharara F, et al. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet. 2022;399:629-655.
2. Barlam TF, Cosgrove SE, Abbo LM, et al. Implementing an antibiotic stewardship program: guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. Clin Infect Dis. 2016;62:e51-e77.
3. Dellit TH, Owens RC, McGowan JE Jr, et al. Infectious Diseases Society of America and Society for Healthcare Epidemiology of America guidelines for developing an institutional programme to enhance antimicrobial stewardship. Clin Infect Dis. 2007;44:159-177.
4. Schuts EC, Hulscher MEJL, Mouton JW, et al. Current evidence on hospital antimicrobial stewardship objectives: a systematic review and meta-analysis. Lancet Infect Dis. 2016;16:847-856.
5. Davey P, Marwick CA, Scott CL, et al. Interventions to improve antibiotic prescribing practices for hospital inpatients. Cochrane Database Syst Rev. 2017;2:CD003543.
6. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71.
7. Page MJ, Moher D, Bossuyt PM, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ. 2021;372:n160.
8. Tamma PD, Avdic E, Keenan JF, et al. What is the more effective antibiotic stewardship intervention: pre-prescription authorisation or post-prescription review with feedback? Clin Infect Dis. 2017;64:537-543.
9. Palmay L, Elligsen M, Walker SAN, et al. Hospital-wide rollout of antimicrobial stewardship: a stepped-wedge randomized trial. Clin Infect Dis. 2014;59:867-874.
10. Thakkar P, Singhal T, Shah S, et al. The implementation and outcome of a two-year prospective audit and feedback-based antimicrobial stewardship programme. J Assoc Physicians India. 2021.
11. Bouadma L, Luyt CE, Tubach F, et al. Use of procalcitonin to reduce patients' exposure to antibiotics in intensive care units: a multicentre

randomised controlled trial. Lancet. 2010;375:463-474.
12. de Jong E, van Oers JA, Beishuizen A, et al. Efficacy and safety of procalcitonin guidance in reducing the duration of antibiotic treatment in critically ill patients: a randomised controlled open-label trial. Lancet Infect Dis. 2016;16:819-827.
13. Dark P, et al. Biomarker-guided antibiotic duration in hospitalised patients with suspected sepsis: the ADAPT-Sepsis randomised clinical trial. JAMA. 2025.
14. Livorsi DJ, et al. Prospective audit and feedback by antibiotic stewardship teams at hospital discharge: a stepped-wedge cluster-randomized clinical trial. JAMA Netw Open. 2026.
15. Ng TM, Phang VY, Young B, et al. Prospective audit and feedback in antimicrobial stewardship: is there value in early reviewing within 48 hours of antibiotic prescription? Int J Antimicrob Agents. 2015;45:168-173.
16. Schweitzer VA, van Werkhoven CH, Baño JR, et al. Narrow-spectrum antibiotics for community-acquired pneumonia in hospitalised adults: a stepped-wedge cluster-randomised non-inferiority trial. Lancet Infect Dis. 2022.
17. Chen JZ, et al. Efficacy and safety of antimicrobial stewardship prospective audit and feedback in patients hospitalised with COVID-19: a pragmatic cluster-randomised non-inferiority trial. Lancet Infect Dis. 2023.
18. Branch-Elliman W, O'Brien W, Strymish J, Itani K, Wyatt C, Gupta K. Association of duration and type of surgical prophylaxis with antimicrobial-associated adverse events. JAMA Surg. 2019;154:590-598.
19. Leone M, Bechis C, Baumstarck K, et al. De-escalation versus continuation of empirical antimicrobial treatment in severe sepsis: a multicentre non-blinded randomised non-inferiority trial. Intensive Care Med. 2014;40:1399-1408.
20. Banerjee R, Teng CB, Cunningham SA, et al. Randomized trial of rapid multiplex polymerase-chain-reaction-based blood-culture identification and susceptibility testing. Clin Infect Dis. 2015;61:1071-1080.
21. Gatechan T, et al. Impact of pharmacist-led education and prospective audit and feedback on antimicrobial dose optimisation in intensive care. 2025.
22. Zimmer AJ, Freifeld AG, Kennedy KR, et al. Multidisciplinary tool kit for febrile neutropenia: stewardship guidelines, *Staphylococcus aureus* epidemiology, and antibiotic-use ratios. J Natl Compr Canc Netw. 2020;18:113-121.
23. Aguilar-Guisado M, Espigado I, Martín-Peña A, et al. Optimisation of empirical antimicrobial therapy in patients with haematological malignancies and febrile neutropenia. Lancet Haematol. 2017;4:e573-e583.
24. Freifeld A, Marchigiani D, Walsh T, et al. A double-blind comparison of empirical oral and intravenous antibiotic therapy for low-risk febrile patients with neutropenia during cancer chemotherapy. N Engl J Med. 1999;341:305-311.
25. Innes HE, Smith DB, O'Reilly SM, Clark PI, Kelly V, Marshall E. Oral antibiotics with early hospital discharge compared with inpatient intravenous antibiotics for low-risk febrile neutropenia in patients with cancer. Br J Cancer. 2003;89:43-49.
26. Carling P, Fung T, Killion A, Terrin N, Barza M. Favourable impact of a multidisciplinary antibiotic-management programme conducted during seven years. Infect Control Hosp Epidemiol. 2003;24:699-706.
27. Fraser GL, Stogsdill P, Dickens JD Jr, Wennberg DE, Smith RP Jr, Prato BS. Antibiotic optimisation: an evaluation of patient safety and economic outcomes. Arch Intern Med. 1997;157:1689-1694.
28. Katsios CM, Burry L, Nelson S, et al. An antimicrobial stewardship program improves antimicrobial treatment by culture site and the quality of antimicrobial prescribing in critically ill patients. Crit Care. 2012;16:R216.
29. Saied T, Hafez SF, Kandeel A, et al. Antimicrobial stewardship to optimise the use of antimicrobials for surgical prophylaxis in Egypt: a multicentre pilot intervention study. Am J Infect Control. 2015;43:e67-e71.
30. Tourmousoglou CE, Yiannakopoulou EC, Kalapothaki V, Bramis J, Papadopoulos JS. Adherence to guidelines for antibiotic prophylaxis in general surgery: a critical appraisal. J Antimicrob Chemother. 2008;61:214-218.
31. van Kasteren MEE, Mannien J, Ott A, Kullberg BJ, de Boer AS, Gyssens IC. Antibiotic prophylaxis and the risk of surgical-site infections following total hip arthroplasty. Clin Infect Dis. 2007;44:921-927.
32. Vaughn VM, Gandhi TN, Chopra V, et al. Antibiotic overuse after hospital discharge: a multi-hospital cohort study. Clin Infect Dis. 2021;73:e4499-e4506.
33. World Health Organization. The WHO AWaRe Antibiotic Book. Geneva: World Health Organization; 2022.