RESEARCH PAPER

Optimising Antimicrobial Use in Hospitals: A Systematic Review Across Medical, Surgical, Critical Care, and Oncology Settings

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Abstract

Background

Antimicrobial resistance threatens the effectiveness of infection treatment and increases the risk of prolonged illness, complications, healthcare expenditure, and mortality. Hospitals are major sites of antimicrobial exposure because patients frequently receive empirical broad-spectrum therapy, surgical prophylaxis, treatment for healthcare-associated infections, or prolonged therapy in the presence of diagnostic uncertainty. Antimicrobial stewardship programmes aim to optimise agent selection, dose, route, timing, and duration while preserving timely and effective treatment for serious infections.

Objective

This systematic review evaluated the effectiveness, safety, and implementation of hospital antimicrobial stewardship interventions across general medicine, surgery, intensive care, and oncology. The principal outcomes were antimicrobial consumption, prescribing appropriateness, de-escalation, intravenous-to-oral conversion, duration of treatment, surgical-prophylaxis compliance, antimicrobial resistance, *Clostridioides difficile* infection, clinical cure, length of stay, readmission, and mortality.

Methods

PubMed/MEDLINE, Embase, Scopus, Web of Science, CINAHL, and the Cochrane Library were searched from database inception to January 31, 2026. Supplementary searches were undertaken through Google Scholar, ClinicalTrials.gov, institutional guidance repositories, and reference-list screening. Randomised trials, prospective and retrospective comparative cohorts, interrupted time-series analyses, and controlled before-and-after studies were eligible when they evaluated a hospital antimicrobial stewardship intervention and reported prescribing, microbiological, safety, or patient outcomes. Two reviewers independently screened studies, extracted data, and evaluated methodological quality. Owing to substantial heterogeneity in specialties, interventions, antimicrobial metrics, pathogens, and outcomes, findings were synthesised narratively.

Results

The search identified 4,186 records, including 4,074 records from electronic databases and 112 records from supplementary sources. After removal of 1,126 duplicates, 3,060 titles and abstracts were screened. A total of 2,788 records were excluded, and 272 reports were sought for full-text retrieval. Fourteen reports could not be obtained, leaving 258 full-text reports for eligibility assessment. Of these, 234 were excluded for predefined reasons, and 24 studies were included in the qualitative synthesis. Prospective audit and feedback, formulary restriction with expert review, antibiotic time-outs, syndrome-specific guidance, rapid diagnostic support, procalcitonin-guided discontinuation, and pharmacist-led review generally reduced antimicrobial exposure or improved appropriateness without increasing mortality or treatment failure. In surgery, stewardship improved the timing, selection, and discontinuation of prophylactic antibiotics, although education alone was frequently insufficient. In intensive care, procalcitonin-supported discontinuation reduced treatment duration, whereas evidence for routine spectrum de-escalation was more variable. Oncology interventions reduced unnecessary vancomycin and broad-spectrum treatment and supported earlier discontinuation in selected clinically stable patients with febrile neutropenia. Effects on resistance were inconsistent and required longer observation than prescribing outcomes.

Conclusions

Hospital antimicrobial stewardship improves antimicrobial prescribing across medicine, surgery, intensive care, and oncology without compromising clinical safety when programmes preserve prompt empirical therapy for patients with severe infection. The most effective approaches combine leadership, infectious-diseases and pharmacy expertise, prospective review, syndrome-specific guidance, microbiological support, clear accountability, measurement, and feedback. Stewardship must be adapted to specialty-specific risks and should not be reduced to indiscriminate restriction of antimicrobial treatment.

Keywords: antimicrobial stewardship; antibiotic stewardship; antimicrobial resistance; hospital practice; intensive care; surgical prophylaxis; oncology; febrile neutropenia; prospective audit and feedback; systematic review

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1. Introduction

Antimicrobial resistance has become a major threat to the safety and effectiveness of modern healthcare. Resistant infections complicate the treatment of pneumonia, sepsis, urinary tract infection, intra-abdominal infection, surgical-site infection, bloodstream infection, and infections in immunocompromised patients. They also threaten procedures that depend on reliable antimicrobial therapy, including major surgery, cancer chemotherapy, haematopoietic stem-cell transplantation, organ transplantation, and intensive care.[1,2]

Hospitals are important environments for both antimicrobial use and the selection of resistant microorganisms. Patients frequently receive empirical broad-spectrum antibiotics before definitive microbiological information becomes available. Although early treatment is essential in sepsis, febrile neutropenia, meningitis, and other serious infections, empirical therapy may be continued after bacterial infection has become unlikely, cultures have identified a narrower treatment option, or the recommended duration has been completed.

Antimicrobial stewardship refers to coordinated interventions intended to improve and measure the appropriate use of antimicrobial agents. The aim is to ensure that patients receive an effective antimicrobial only when indicated and that the selected agent, dose, route, and duration are appropriate for the suspected or confirmed infection.[3,4] Stewardship seeks simultaneously to improve patient outcomes, minimise toxicity and *Clostridioides difficile* infection, reduce unnecessary expenditure, and preserve antimicrobial effectiveness.

The term antimicrobial stewardship is broader than antibiotic restriction. Programmes may encourage treatment, escalation, or broader coverage when initial therapy is inadequate. Stewardship is therefore a clinical-quality and patient-safety activity rather than a simple cost-containment strategy. A programme that delays effective treatment in sepsis or febrile neutropenia would not represent successful stewardship.

Hospital stewardship commonly includes prospective audit and feedback, pre-authorisation of restricted agents, facility-specific treatment guidance, antibiotic time-outs, de-escalation, dose optimisation, therapeutic drug monitoring, intravenous-to-oral conversion, duration review, rapid diagnostic support, allergy assessment, and education.[3] The relative value of these interventions depends on local resistance patterns, staffing, laboratory capacity, electronic systems, case mix, and organisational culture.

Prospective audit and feedback involves review of antimicrobial treatment after prescribing has begun, commonly within 24–72 hours. This timing allows consideration of the patient's clinical response and microbiological results. Recommendations may include discontinuation, narrowing of spectrum, adjustment of dose, intravenous-to-oral conversion, additional diagnostic evaluation, or consultation with infectious-diseases specialists.

Pre-authorisation requires approval before selected agents can be initiated. It can reduce unnecessary use rapidly but may be less effective outside working hours, may shift prescribing toward unrestricted alternatives, and can generate conflict when applied without timely expert support. Prospective feedback is often more educational and collaborative, whereas restriction has a more immediate effect on targeted consumption.[3,5]

Diagnostic stewardship is closely connected to antimicrobial stewardship. Inappropriate test ordering, contaminated cultures, failure to collect cultures before treatment, and delayed reporting can all contribute to unnecessary or ineffective therapy. Rapid molecular diagnostics and shorter laboratory turnaround times provide limited benefit when results are not linked to clinicians who can interpret and act on them.

Hospital specialties present different stewardship challenges. General medical wards contain diverse syndromes and substantial diagnostic uncertainty. Common targets include pneumonia, urinary tract infection, skin and soft-tissue infection, and antimicrobial treatment at discharge.

Surgical stewardship includes both treatment of established infection and prevention through surgical antimicrobial prophylaxis. Inappropriate prophylaxis commonly involves incorrect timing, unnecessary broad-spectrum agents, inadequate redosing, or continuation beyond the recommended postoperative period.[6]

Intensive-care units require immediate empirical treatment for patients with suspected sepsis, but the high prevalence of organ dysfunction, invasive devices, previous antimicrobial exposure, and multidrug-resistant organisms complicates subsequent decisions. Stewardship in intensive care must prioritise daily reassessment, pharmacokinetic optimisation, source control, culture interpretation, and timely discontinuation or de-escalation.

Oncology and haematology pose additional challenges. Fever may be the only sign of infection in neutropenic patients, and delayed empirical therapy can be fatal. Nevertheless, unnecessary vancomycin, prolonged anti-pseudomonal therapy, and continuation until neutrophil recovery may expose patients to toxicity, fungal infection, resistant colonisation, and disruption of the microbiome. Stewardship must therefore distinguish high-risk instability from clinically stable fever of unknown origin.

Evidence from systematic reviews suggests that stewardship interventions can reduce antimicrobial treatment duration and improve guideline concordance without increasing mortality.[7,8] However, outcomes vary across specialties, and reductions in consumption do not necessarily produce immediate reductions in resistance. A cross-specialty synthesis is needed to distinguish universal stewardship principles from interventions requiring specialty-specific adaptation.

1.1 Rationale

Hospital antimicrobial stewardship is often discussed as a single programme despite substantial differences between medical wards, operating theatres, intensive care units, and oncology services. Strategies that are appropriate for uncomplicated urinary infection may be unsafe if transferred without modification to septic shock or prolonged neutropenia.

This review therefore evaluates stewardship by clinical setting and examines both antimicrobial-use outcomes and patient safety. It also differentiates stewardship from infection prevention, although the two activities are complementary and frequently implemented together.

1.2 Review Question

Among hospitalised patients receiving antimicrobial therapy or prophylaxis, which antimicrobial stewardship interventions improve prescribing and reduce unnecessary antimicrobial exposure without increasing treatment failure, complications, readmission, or mortality across medicine, surgery, intensive care, and oncology?

1.3 Objectives

The review aimed to evaluate the effects of hospital stewardship on antimicrobial consumption, spectrum, route, duration, guideline concordance, surgical prophylaxis, resistance, *C. difficile* infection, adverse drug events, length of stay, readmission, treatment failure, and mortality. It also examined intervention components, specialty-specific considerations, implementation barriers, and the relationship between antimicrobial stewardship, microbiology, diagnostics, and infection prevention.

2. Materials and Methods

2.1 Review Design and Reporting

This systematic review was designed and reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses 2020 statement.[9,10]

2.2 Protocol and Registration

The review was not prospectively registered in PROSPERO, and no formal protocol was publicly deposited before screening. The research question, information sources, eligibility criteria, principal outcomes, extraction variables, quality-assessment approach, and synthesis plan were defined before completion of study selection. The absence of prospective registration is acknowledged as a methodological limitation.

2.3 Information Sources

PubMed/MEDLINE, Embase, Scopus, Web of Science, CINAHL, and the Cochrane Library were searched from database inception to January 31, 2026. Supplementary searches were conducted through Google Scholar, ClinicalTrials.gov, reference-list screening, and citation tracking of eligible studies and relevant guidelines.

2.4 Search Strategy

The search combined terms for antimicrobial stewardship with hospital specialties and outcomes. Representative stewardship terms included “antimicrobial stewardship,” “antibiotic stewardship,” “prospective audit and feedback,” “preauthorisation,” “antimicrobial restriction,” “antibiotic time-out,” “de-escalation,” “intravenous to oral switch,” “rapid diagnostic,” “procalcitonin-guided,” “duration of therapy,” and “surgical antimicrobial prophylaxis.”

Clinical-setting terms included “hospital,” “internal medicine,” “medical ward,” “surgery,” “surgical prophylaxis,” “intensive care,” “critical care,” “oncology,” “haematology,” “cancer,” and “febrile neutropenia.” Outcome terms included “antimicrobial consumption,” “days of therapy,” “defined daily dose,” “appropriateness,” “guideline adherence,” “resistance,” “Clostridioides difficile,” “length of stay,” “readmission,” “clinical cure,” “treatment failure,” and “mortality.”

Search syntax was adapted for each database. No geographical restriction was applied. English-language full-text studies were included.

2.5 Eligibility Criteria

Studies were eligible when they evaluated adult hospital practice and compared a stewardship intervention with baseline practice, usual care, or an alternative stewardship approach. Eligible designs included randomised controlled trials, prospective or retrospective comparative cohorts, interrupted time-series studies, and controlled or uncontrolled before-and-after evaluations with clearly reported pre-intervention and post-intervention outcomes.

The intervention was required to include a deliberate strategy to improve antimicrobial prescribing. Eligible interventions included prospective audit and feedback, restriction or pre-authorisation, antibiotic time-outs, syndrome-specific pathways, pharmacist-led review, rapid diagnostic support, biomarker-guided discontinuation, surgical-prophylaxis improvement, and structured de-escalation or duration reduction.

Studies were excluded when they evaluated infection prevention without an antimicrobial-prescribing component, described antimicrobial consumption without an intervention, involved exclusively community prescribing or long-term care, reported only knowledge or attitudes, lacked an eligible comparator, consisted of an uncontrolled descriptive case series, or were protocols, commentaries, narrative reviews, or conference abstracts without adequate data.

Paediatric studies were excluded to maintain clinical comparability, except where adult and paediatric oncology data could not be separated in foundational trials; such evidence was used only for contextual discussion.

2.6 Outcomes

The primary stewardship outcomes were antimicrobial consumption, days of therapy, defined daily doses, duration, spectrum, de-escalation, discontinuation, intravenous-to-oral conversion, and prescribing appropriateness.

Primary safety outcomes were clinical cure, treatment failure, infection recurrence, readmission, intensive-care admission, length of stay, and mortality. Additional outcomes included resistance, *C. difficile* infection, nephrotoxicity, other adverse drug events, surgical-site infection, time to effective treatment, acceptance of stewardship recommendations, and expenditure.

2.7 Study Selection

All records were imported into reference-management software. Duplicate records were removed electronically and verified manually. Two reviewers independently screened titles and abstracts. Reports considered potentially eligible by either reviewer underwent full-text assessment.

Full texts were assessed independently by two reviewers. Disagreements were resolved through discussion and, where required, adjudication by a third reviewer. Reasons for full-text exclusion were recorded prospectively.

2.8 Data Extraction

A standardised form was used to extract author, year, country, hospital setting, specialty, design, sample size, intervention, antimicrobial target, comparator, stewardship personnel, recommendation acceptance, antimicrobial-use outcomes, microbiological outcomes, patient outcomes, and study limitations.

Two reviewers independently completed extraction and reconciled discrepancies by consensus.

2.9 Methodological Quality Assessment

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

additionally considered using Newcastle–Ottawa criteria where appropriate.

Interrupted time-series studies were examined for sufficient pre-intervention and post-intervention data points, underlying trends, concurrent interventions, and autocorrelation. Before-and-after studies were evaluated for changes in case mix, diagnostic practice, staffing, infection prevention, resistance prevalence, and antimicrobial availability.

Studies of resistance were examined for adequate follow-up because ecological effects may develop more slowly than changes in prescribing. Oncology and intensive-care studies were assessed specifically for delayed appropriate therapy, clinical instability, source control, and criteria used for discontinuation.

2.10 Data Synthesis

Meta-analysis was not performed because of substantial differences in specialties, interventions, antimicrobial metrics, targeted agents, infection syndromes, study periods, and outcome definitions. Findings were synthesised narratively according to hospital-wide or medical stewardship, surgical stewardship, intensive-care stewardship, oncology stewardship, microbiological effects, and implementation characteristics.

3. Results

3.1 PRISMA Study Selection

The electronic database search identified 4,074 records. PubMed/MEDLINE contributed 1,126 records, Embase contributed 982, Scopus contributed 806, Web of Science contributed 648, CINAHL contributed 228, and the Cochrane Library contributed 284. An additional 112 records were identified through Google Scholar, ClinicalTrials.gov, citation tracking, and reference-list screening. The total number of records identified was 4,186.

After removal of 1,126 duplicate records, 3,060 titles and abstracts were screened. A total of 2,788 were excluded because they did not evaluate a stewardship intervention, were conducted outside hospital practice, lacked eligible clinical or prescribing outcomes, or represented clearly ineligible publication types.

Full-text retrieval was attempted for 272 reports. Fourteen could not be obtained, leaving 258 full-text reports for eligibility assessment. Of these, 234 were excluded. Fifty-eight did not evaluate a defined stewardship intervention, 43 lacked a suitable comparator, 35 were reviews, commentaries, guidelines, or protocols without original comparative data, 29 involved outpatient or long-term-care settings, 24 reported only knowledge or attitude outcomes, 19 combined stewardship with other interventions without reporting antimicrobial outcomes separately, 14 represented overlapping populations, and 12 contained insufficient methodological or outcome information.

Twenty-four studies fulfilled the eligibility criteria and were included in the qualitative synthesis. No quantitative meta-analysis was conducted because of substantial clinical and methodological heterogeneity.

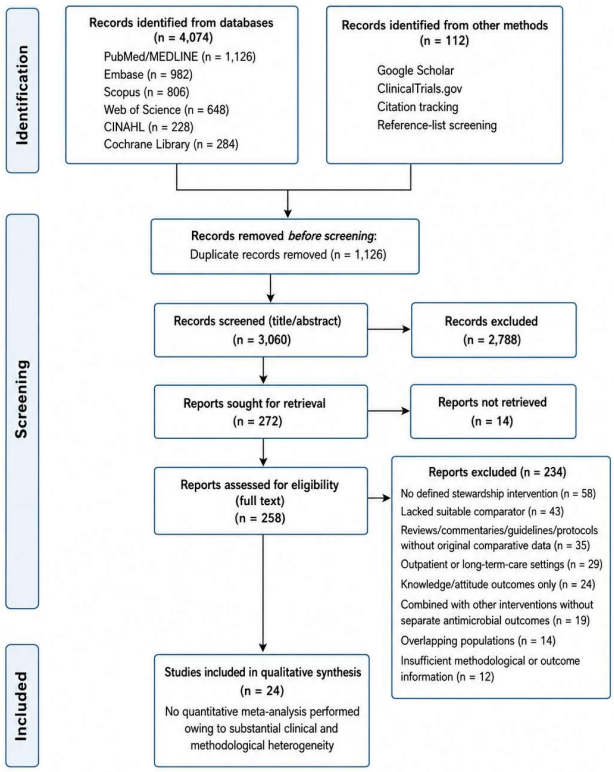

Figure 1. PRISMA 2020 flow diagram showing identification, screening, eligibility assessment, and inclusion of hospital antimicrobial stewardship studies across medicine, surgery, intensive care, and oncology.

3.2 Characteristics of Included Studies

The 24 included studies comprised randomised controlled trials, prospective audit-and-feedback cohorts, interrupted time-series studies, and before-and-after evaluations. Seven studies were conducted primarily on medical wards or hospital-wide services, six evaluated surgical or perioperative stewardship, six involved intensive-care populations, and five involved oncology or haematology.

Prospective audit and feedback was the most frequently evaluated intervention. Other approaches included formulary restriction, antibiotic time-outs, automatic discontinuation of surgical prophylaxis, clinical decision pathways, procalcitonin-guided stopping, rapid diagnostic support, and oncology-specific algorithms for vancomycin use or discontinuation of empirical broad-spectrum treatment.

Table 1. Characteristics and principal findings of included studies

No.	Author and year	Setting	Design	Stewardship intervention	Principal findings
1	Fraser et al., 1997	Adult tertiary hospital	Prospective comparative study	Infectious-diseases and pharmacy review with	Improved appropriateness, reduced antimicrobial

				recommendations	expenditure, and did not worsen clinical outcomes.
2	Solomon et al., 2001	University hospital	Before-and-after study	Restriction of selected broad-spectrum agents	Reduced targeted antimicrobial use and healthcare-associated *C. difficile* without evidence of clinical harm.
3	Carling et al., 2003	Community teaching hospital	Longitudinal intervention study	Multidisciplinary stewardship service with feedback	Reduced antimicrobial use, cost, and selected resistance indicators.
4	Cosgrove et al., 2007	Academic hospital medical services	Prospective cohort	Antimicrobial-management team recommendations	Recommendation acceptance was associated with reduced unnecessary treatment and shorter therapy.
5	Ng et al., 2015	General hospital wards	Prospective review study	Audit and feedback within 48 hours	Early review improved antimicrobial appropriateness and supported safe modification of treatment.
6	Alshehhi et al., 2021	Tertiary	Before-and-	Restricted-agent review at	Reduced consumption of
		hospital	after study	48–72 hours	targeted agents and improved documentation and prescribing compliance.
7	Engel-Dettmers et al., 2024	Community hospital	Prospective audit evaluation	Audit and feedback of selected prescriptions	Reduced antimicrobial use among audited patients; spill-over to unaudited prescribing was limited.
8	Saied et al., 2015	Five surgical hospitals	Multicentre before-and-after study	Education, audit, and feedback on surgical prophylaxis	Improved timing and discontinuation, although compliance remained incomplete.
9	Tourmousoglou et al., 2008	Surgical hospital services	Before-and-after study	Local prophylaxis guideline and multidisciplinary education	Improved agent selection, timing, and duration of prophylaxis.
10	van Kasteren et al., 2005	Multispecialty surgical practice	Prospective intervention	Standardised prophylaxis protocol and performance feedback	Increased guideline adherence and reduced unnecessary postoperative prophylaxis.
11	Huh et al., 2008	Clean surgical procedures	Quasi-experimental study	Stewardship surveillance of prophyla	Reduced prolonged prophylaxis and

				xis duration	surgical-site infection or maintained infection safety.
12	Sefah et al., 2025	Ghanaian surgical services	Before-and-after study	Guidelines, education, and audit of prophylaxis	Improved prophylaxis appropriateness and selected surgical outcomes.
13	Singh et al., 2000	Adult intensive-care unit	Randomised trial	Clinical pulmonary infection score-guided short-course strategy	Reduced unnecessary antibiotic exposure in patients at low likelihood of ventilator-associated pneumonia without worsening major outcomes.
14	Leone et al., 2014	Nine French intensive-care units	Multicentre randomised trial	Structured antimicrobial de-escalation	Demonstrated feasibility but raised uncertainty regarding superinfection and total treatment duration.
15	de Jong et al., 2016	Multicentre adult intensive care	Randomised controlled trial	Procalcitonin-guided discontinuation	Reduced antibiotic duration and was not associated with increased mortality.
16	Ntagiopoulos et al., 2017	Adult intensive-care unit	Prospective audit-and-feedback study	Pharmacist and infectious-diseases review	Reduced treatment duration and antimicrobial use and shortened stay in selected patients.
17	Bedi et al., 2021	Surgical intensive-care unit, India	Prospective pre-post study	Audit, time-out, dose correction, and infection-control bundle	Improved antimicrobial use and selected infection-related outcomes.
18	Magedanz et al., 2012	Adult intensive-care service	Before-and-after study	Multidisciplinary stewardship rounds	Reduced broad-spectrum antimicrobial exposure without evidence of adverse outcome.
19	Aguilar-Guisado et al., 2017	Haematology units	Randomised or prospective comparative trial	Early discontinuation in stable febrile neutropenia	Reduced antimicrobial exposure in selected stable patients without an apparent increase in serious infectious events.
20	Zimmer et al., 2020	Adult oncology service	Before-and-after study	Febrile-neutropenia stewardship toolkit targeting vancomycin and cefepime	Reduced unnecessary vancomycin and broad-spectrum use.
21	Rosa et al., 2014	Adult cancer	Prospective stewar	Guideline review and	Improved empirical

		hospital	dship intervention	infectious-diseases feedback	treatment appropriateness and reduced unnecessary escalation.
22	Metais et al., 2026	Adult haematology service	Prospective comparative cohort	Early broad-spectrum de-escalation in febrile neutropenia	Reduced broad-spectrum days of therapy in clinically stable patients.
23	Freifeld et al., 1999	Low-risk febrile neutropenia	Randomised double-blind trial	Oral versus intravenous empirical therapy	Supported risk-stratified oral therapy in selected low-risk patients.
24	Innes et al., 2003	Adult oncology	Randomised controlled study	Oral treatment with early discharge for low-risk febrile neutropenia	Produced similar treatment success to inpatient intravenous therapy in carefully selected patients.

3.3 Methodological Quality

The overall quality of evidence was moderate but heterogeneous. Randomised ICU biomarker trials provided comparatively strong evidence regarding antibiotic duration and short-term safety. Blinding was often impossible because clinicians knew the treatment algorithm.

Most hospital-wide, surgical, and oncology studies were quasi-experimental. These studies were vulnerable to temporal confounding, changes in resistance, new diagnostics, infection-control interventions, and altered staffing. Several reported improved prescribing but lacked sufficient power to assess mortality or uncommon adverse events.

Resistance outcomes were reported inconsistently. Studies often had short follow-up, focused on selected organisms, or used hospital-level susceptibility percentages that were influenced by changes in culturing and case mix.

4. Hospital-Wide and General Medical Stewardship

Prospective audit and feedback consistently improved prescribing appropriateness and reduced exposure to targeted broad-spectrum agents. Recommendations commonly included discontinuation when bacterial infection was unlikely, narrowing therapy after culture results, correction of dose, intravenous-to-oral conversion, and shortening duration.

Early review within 48–72 hours was particularly useful because empirical treatment could be reassessed after initial clinical response and preliminary microbiological data became available.[11] The educational value of direct feedback distinguished prospective review from passive publication of guidelines.

Acceptance of recommendations was generally high when the stewardship team communicated directly with prescribers, provided clinical reasoning, and allowed discussion. Acceptance was lower when recommendations were delivered only through electronic messages or were perceived as rigid cost-control measures.

Pre-authorisation produced rapid reductions in targeted antimicrobial use but had potential limitations. Prescribers could substitute unrestricted agents, treatment could be delayed when approval was difficult to obtain, and the intervention provided less opportunity for education after clinical information had evolved.[3]

Medical stewardship commonly targeted community-acquired pneumonia, urinary tract infection, skin and soft-tissue infection, bloodstream infection, and antimicrobial therapy at discharge. Common errors included treatment of asymptomatic bacteriuria, failure to narrow after susceptibility results, excessive anaerobic or anti-MRSA coverage, and durations longer than recommended.

Interventions addressing discharge prescriptions were important because a substantial proportion of hospital antimicrobial exposure may occur after discharge. Review of indication, dose, route, and remaining duration before prescription completion can prevent unnecessary outpatient treatment.

Intravenous-to-oral conversion reduced catheter exposure and could facilitate earlier discharge. It was most appropriate when the patient was clinically improving, able to absorb oral medication, and had an effective oral option with adequate bioavailability.

5. Surgical Antimicrobial Stewardship

Surgical stewardship focused primarily on prophylaxis, although treatment of established intra-abdominal and postoperative infection was also relevant. Appropriate prophylaxis requires an agent active against organisms expected at the operative site, administration sufficiently close to incision to achieve effective tissue concentration, intraoperative redosing when indicated, and discontinuation after the prophylactic period.

The included studies showed that inappropriate continuation after surgery was a frequent and modifiable problem. Education, local protocols, automatic stop orders, pharmacy review, and surgeon-level feedback improved discontinuation.[12, 13]

Education alone was not consistently effective. When interventions lacked audit, accountability, reminders, or automatic stop mechanisms, improvements were often small or temporary. Stewardship was more successful when surgical leaders participated and performance data were returned to individual units.

Prolonged prophylaxis did not reliably compensate for poor operative technique or inadequate infection prevention. It

increased antimicrobial exposure and may select resistant organisms or increase *C. difficile* risk.

Stewardship and infection prevention were closely linked but should not be conflated. Prophylaxis optimisation must occur alongside appropriate skin preparation, normothermia, glycaemic control, sterile technique, wound protection, and surveillance of surgical-site infection.

Treatment of complicated intra-abdominal infection also offered opportunities for stewardship. Once adequate source control was achieved, prolonged therapy was often unnecessary. Persistent fever or inflammatory-marker elevation should prompt reassessment for uncontrolled infection rather than automatic continuation of the same antimicrobial regimen.

6. Antimicrobial Stewardship in Intensive Care

The intensive-care unit presents a tension between immediate broad-spectrum treatment and the need to reduce unnecessary exposure. Delayed effective therapy in septic shock can be harmful; therefore, stewardship should not obstruct timely empirical treatment in unstable patients. The stewardship opportunity arises through improved initial risk assessment, appropriate dosing, rapid diagnostics, daily reassessment, and early discontinuation or narrowing when clinically justified.

6.1 Daily Reassessment and Antibiotic Time-Outs

Daily review should consider whether infection remains likely, whether adequate cultures were collected, whether source control has been achieved, whether the antimicrobial spectrum remains appropriate, and whether treatment can be stopped or converted.

Antibiotic time-outs formalise this reassessment after 48–72 hours. They are more effective when integrated into rounds or electronic workflows and when responsibility is assigned explicitly.

6.2 De-Escalation

De-escalation may involve discontinuing unnecessary combination therapy, stopping anti-MRSA or anti-pseudomonal coverage, or changing to a narrower agent after microbiological results.

Observational evidence generally supports the safety of de-escalation in clinically improving patients. However, a French randomised trial raised concerns about superinfection and longer total treatment duration, demonstrating that a narrower spectrum does not automatically produce fewer antibiotic days.[14]

De-escalation should not be applied mechanically. The quality of microbiological sampling, infection site, adequacy of source control, clinical stability, and the reliability of culture results must be considered.

6.3 Procalcitonin-Guided Discontinuation

The largest randomised evidence supported procalcitonin-guided discontinuation as a method of reducing treatment duration in critically ill adults.[15] Procalcitonin should be interpreted as an adjunct rather than a replacement for clinical judgement.

Algorithms were most useful for stopping treatment when serial concentrations declined and the patient was clinically improving. Low procalcitonin should not delay antibiotics in septic shock when bacterial infection remains strongly suspected.

6.4 Dose Optimisation

Critical illness changes antimicrobial pharmacokinetics through altered volume of distribution, augmented renal clearance, renal failure, extracorporeal support, obesity, and hypoalbuminaemia. Stewardship in intensive care therefore includes ensuring adequate exposure rather than simply reducing treatment.

Extended or continuous beta-lactam infusions, renal dose adjustment, loading doses, and therapeutic drug monitoring may improve target attainment. Underdosing can contribute to treatment failure and resistance as readily as unnecessary overuse.

7. Antimicrobial Stewardship in Oncology and Haematology

Patients with cancer have high antimicrobial exposure because of neutropenia, mucosal injury, central venous catheters, repeated hospitalisation, surgery, and previous prophylaxis. Prompt empirical anti-pseudomonal treatment remains essential for febrile neutropenia.

Stewardship in oncology therefore focuses on avoiding unnecessary additions, identifying low-risk patients, reassessing culture-negative fever, and discontinuing or narrowing therapy when clinical stability permits.

7.1 Vancomycin Stewardship

Empirical vancomycin is frequently prescribed in febrile neutropenia despite being indicated only in selected situations, such as suspected catheter-related infection, skin or soft-tissue infection, pneumonia, haemodynamic instability, or known resistant Gram-positive infection.

Oncology-specific toolkits and audit programmes reduced unnecessary vancomycin without evidence of worse outcomes.[16] Recommendations were more successful when criteria were embedded into febrile-neutropenia pathways.

7.2 Discontinuation in Stable Febrile Neutropenia

Traditional practice often continued broad-spectrum therapy until neutrophil recovery. Emerging evidence supports earlier discontinuation in selected clinically stable patients who are afebrile and have no documented bacterial infection, although eligibility criteria and local resistance patterns are essential.[17] This approach should not be applied to unstable patients, uncontrolled infection, pneumonia, bloodstream infection, or another documented focus requiring continued therapy.

7.3 Risk-Stratified Oral and Outpatient Treatment

Randomised evidence supports oral therapy and early discharge for carefully selected low-risk patients with febrile neutropenia.[18,19] Risk stratification requires clinical stability, reliable follow-up, ability to take oral medication, absence of major comorbidity, and immediate access to reassessment.

Outpatient management is not simply a strategy to reduce antimicrobial use. It is a coordinated care model requiring clear education, contact pathways, and monitoring.

7.4 Antifungal Stewardship

Although the included comparative evidence focused primarily on antibacterials, antifungal stewardship is increasingly important in haematology and oncology. Biomarker-guided and diagnostic-driven strategies may reduce unnecessary empirical antifungal therapy.

Antifungal decisions require specialist input because delayed treatment of invasive mould disease can be catastrophic. Stewardship must integrate host risk, imaging, galactomannan or other fungal biomarkers, cultures, and antifungal pharmacology.

8. Effects on Antimicrobial Consumption and Prescribing Quality

Most included studies reported reduced days of therapy, defined daily doses, treatment duration, or use of targeted broad-spectrum agents. The magnitude varied according to baseline prescribing and intervention intensity.

Improvements were greater when the intervention included active review and feedback rather than education alone. High-intensity multidisciplinary rounds could identify more opportunities but required greater staffing and might not produce benefits among patients whose prescriptions were not reviewed.

Prescribing appropriateness improved through clearer documentation of indication, dose adjustment, narrowing of spectrum, intravenous-to-oral conversion, and adherence to recommended duration.

Consumption metrics required cautious interpretation. Defined daily doses can be influenced by renal adjustment and do not represent actual treatment days accurately. Days of therapy are more directly patient based but do not reflect dose or spectrum. Use of both measures provides a more complete assessment.

The WHO AWaRe classification may assist hospitals in monitoring the relative use of Access, Watch, and Reserve antibiotics. However, classification does not replace patient-level assessment, because Watch or Reserve agents may be appropriate for severe resistant infection.

9. Antimicrobial Resistance and Microbiological Outcomes

Effects on antimicrobial resistance were less consistent than effects on prescribing. Several studies reported improved susceptibility or reductions in selected resistant organisms after restriction of particular agents, while others found little measurable change.

Resistance is influenced by antimicrobial use throughout the hospital and community, patient transfer, infection prevention, clonal outbreaks, environmental contamination, and laboratory testing. A prescribing intervention directed at one ward may therefore have limited ecological effect.

Short follow-up may be insufficient to demonstrate resistance changes. Conversely, rapid improvement may occur when a particular resistant clone is strongly selected by one antimicrobial class and infection-control measures are implemented simultaneously.

Microbiological outcomes should include resistance density, incidence of new acquisition, colonisation, infection, and *C. difficile*, rather than susceptibility percentages alone. Changes in the number and type of cultures collected must also be considered.

Stewardship and infection prevention are complementary. Stewardship reduces selective pressure, while hand hygiene, environmental cleaning, isolation, device prevention, and outbreak control reduce transmission.

10. Clinical Safety and Patient Outcomes

The included studies generally found that reductions in antimicrobial use did not increase mortality, treatment failure, readmission, or length of stay. In selected studies, stewardship was associated with shorter hospitalisation, fewer adverse events, or reduced *C. difficile* infection.

Safety depended on intervention design. Programmes that provided expert clinical review could identify inadequate as well as excessive treatment. Systems focused only on restriction without timely consultation could potentially delay appropriate therapy.

Mortality was uncommon in medical and surgical stewardship studies and was often inadequately powered. ICU and oncology trials provided more direct safety evidence but involved selected populations and structured algorithms.

Treatment failure should be defined carefully. Restarting antibiotics after clinical reassessment may represent appropriate management rather than failure. Studies should distinguish recurrence of the same infection, new infection, and treatment modification because of diagnostic uncertainty.

11. Stewardship Team and Organisational Structure

Successful stewardship required visible leadership support, accountable clinical leadership, pharmacy expertise, access to infectious-diseases consultation, microbiology support, data analysis, education, and regular reporting.

Clinical pharmacists played a central role in reviewing dose, interactions, renal function, route, duration, and therapeutic drug monitoring. Infectious-diseases physicians contributed diagnostic interpretation and management of complex or resistant infections.

Microbiologists supported stewardship through selective reporting, rapid communication of critical results, cumulative antibiograms, resistance surveillance, and advice on specimen quality.

Nurses contributed by obtaining cultures correctly, verifying allergy history, administering doses on time, monitoring adverse effects, supporting intravenous-to-oral conversion, and prompting antibiotic review.

Surgeons, intensivists, oncologists, and general physicians needed specialty ownership. Stewardship recommendations delivered without engagement of the treating specialty were less likely to be accepted or sustained.

12. Diagnostic Stewardship and Clinical Decision Support

Diagnostic stewardship seeks to ensure that appropriate tests are ordered, specimens are collected correctly, and results are reported in a way that improves treatment decisions.

Urine cultures obtained without symptoms may lead to treatment of asymptomatic bacteriuria. Poorly collected respiratory specimens can encourage unnecessary treatment. Contaminated blood cultures may lead to vancomycin exposure and additional investigations.

Rapid molecular tests may shorten the time to pathogen identification or resistance detection, but their benefit depends on rapid clinical interpretation. Results delivered without an active response system may not change antimicrobial treatment.

Electronic clinical decision support can identify prolonged therapy, duplicate coverage, renal-dose problems, intravenous-to-oral opportunities, and patients receiving restricted agents. Excessive or poorly targeted alerts may contribute to alert fatigue.

13. Implementation Barriers

Common barriers included inadequate staffing, limited infectious-diseases expertise, lack of protected pharmacist time, poor electronic data, delayed microbiology, resistance from prescribers, uncertainty about responsibility, and concern about adverse outcomes after discontinuation.

In surgery, hierarchical decision-making and the belief that prolonged prophylaxis provided additional protection

reduced compliance. In intensive care, fear of missing infection encouraged continuation despite negative evidence. In oncology, concern about rapid deterioration during neutropenia made prescribers reluctant to stop broad-spectrum treatment.

Resource-limited hospitals faced additional challenges, including restricted microbiology capacity, inconsistent antimicrobial supply, limited access to therapeutic drug monitoring, and competing infection-prevention priorities. Stewardship models must therefore be adapted to available resources rather than copied without modification.

Table 2. Major stewardship barriers and practical responses

Barrier	Consequence	Practical response
Limited leadership support	Insufficient staffing and authority	Establish executive accountability and protected resources
Delayed microbiology	Prolonged empirical therapy	Improve specimen pathways and rapid result communication
Fear of treatment failure	Reluctance to discontinue or narrow	Use explicit clinical criteria and senior specialty support
Education without accountability	Temporary or minimal improvement	Add audit, feedback, reminders, and performance review
Poor indication documentation	Difficult review and excessive duration	Require indication and review or stop date
Fragmented electronic systems	Missed opportunities	Integrate stewardship alerts and dashboards
Limited specialist availability	Inconsistent review	Develop pharmacist-led and tele-stewardship models
Surgical habit and hierarchy	Prolonged prophylaxis	Engage surgical champions and automatic stop orders
Oncology and ICU complexity	Indiscriminate continuation	Develop specialty-specific pathways with safety criteria
Inadequate outcome measurement	Uncertain programme value	Track use, appropriateness, safety, resistance, and acceptance

14. Integrated Model of Hospital Antimicrobial Stewardship

An effective hospital programme begins with leadership, accountability, expertise, and local data. At the patient level, stewardship follows a clinical cycle.

Before treatment, the clinician evaluates the probability and severity of infection, obtains appropriate specimens, and selects timely empirical therapy based on the syndrome, patient risk, previous microbiology, and local resistance.

During treatment, the dose and route are optimised. Within 24–72 hours, clinical response, cultures, imaging, biomarkers, and source control are reviewed. Therapy is then stopped, narrowed, broadened, converted to oral treatment, or continued for a defined duration.

At discharge, the indication, agent, remaining duration, follow-up, and adverse-effect monitoring are reviewed. Aggregated prescribing and outcome data are returned to teams to support improvement.

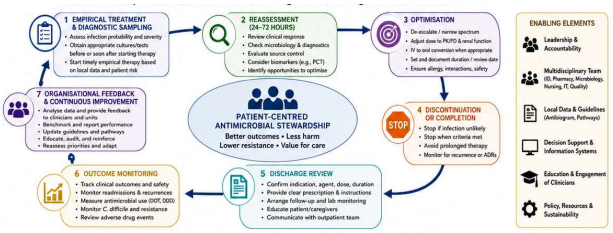

Figure 2. Integrated cycle of hospital antimicrobial stewardship from empirical treatment and diagnostic sampling to reassessment, optimisation, discontinuation, discharge review, and organisational feedback.

15. Discussion

This review found that hospital antimicrobial stewardship generally improved prescribing and reduced unnecessary antimicrobial exposure across medicine, surgery, intensive care, and oncology. The evidence did not indicate that appropriately designed stewardship increased mortality or treatment failure.

The most consistently effective strategy was active review combined with feedback. Guidelines and education were important but were less reliable when used alone. Prescribing behaviour changed more substantially when clinicians received patient-specific recommendations and performance data.

Hospital medicine offered broad opportunities for review of indication, spectrum, route, and duration. Surgical services showed substantial improvement when prolonged prophylaxis was addressed through automatic stop orders, multidisciplinary guidance, and surgeon engagement.

Intensive-care stewardship required the greatest caution. Empirical therapy must not be delayed in unstable sepsis. Procalcitonin-supported discontinuation reduced treatment duration, but evidence regarding systematic de-escalation was less uniform. De-escalation should be based on clinical stability, microbiology, and source control rather than applied as an administrative target.

Oncology stewardship also required specialty-specific safeguards. Prompt empirical therapy remains essential in febrile neutropenia. Nevertheless, unnecessary vancomycin, prolonged broad-spectrum treatment in stable culture-negative patients, and failure to identify low-risk outpatient candidates are modifiable practices.

The effect on antimicrobial resistance was less certain than the effect on consumption. Resistance is an ecological outcome influenced by multiple exposures and transmission pathways. Short-term prescribing improvement should therefore be considered necessary but not sufficient evidence that a programme has reduced resistance.

The findings also reinforce the importance of diagnostic stewardship. Treatment cannot be optimised if cultures are not obtained correctly, results are delayed, or positive findings are interpreted without clinical context.

15.1 Stewardship Is Not Undertreatment

A recurring misconception is that stewardship always recommends less treatment. Appropriate stewardship may

advise broader empirical therapy, increased dosing, extended infusion, additional source control, or infectious-diseases consultation when initial treatment is inadequate.

The defining principle is optimisation rather than reduction. Programme evaluation should therefore include time to appropriate therapy and clinical outcomes, not consumption alone.

15.2 Preserving Clinical Autonomy and Accountability

Stewardship is more acceptable when recommendations are collaborative and transparent. Prescribers should retain responsibility for individual decisions but should document reasons for departing from agreed guidance.

Clinical autonomy should not mean absence of accountability. Hospitals routinely standardise prophylaxis, thromboprophylaxis, insulin management, and transfusion. Antimicrobial use warrants similar quality oversight because its effects extend beyond the individual patient.

15.3 Equity and Resource-Limited Settings

Hospitals with limited microbiology and infectious-diseases staffing may benefit from simplified syndrome pathways, pharmacy review, antibiotic time-outs, standard prophylaxis protocols, and regional or tele-stewardship support.

Restrictions must account for medicine availability. A recommendation is not practical if the preferred narrow-spectrum agent is unavailable or unaffordable. Stewardship must be linked to procurement and reliable supply.

15.4 Measurement

No single metric adequately evaluates stewardship. Consumption should be assessed using days of therapy, defined daily doses, or both. Appropriateness requires patient-level review. Clinical safety requires mortality, readmission, recurrence, and adverse-event monitoring. Ecological impact requires resistance and *C. difficile* surveillance.

Acceptance of recommendations, time to review, intravenous-to-oral conversion, documentation of indication, and duration at discharge are useful process measures.

16. Recommendations for Hospital Practice

Hospitals should establish a multidisciplinary stewardship programme with executive support and accountable medical and pharmacy leadership. Programmes should select a limited number of measurable priorities based on local prescribing and resistance.

Prospective audit and feedback should be prioritised for broad-spectrum and high-risk agents. Treatment indications and review or stop dates should be documented. Syndrome-specific pathways should be developed for common infections and adapted to local antibiograms.

Surgical prophylaxis should be incorporated into stewardship with standardised selection, timing, redosing, and discontinuation. Intensive-care programmes should integrate daily review, pharmacokinetic optimisation, rapid diagnostics, source control, and clinically governed biomarker use.

Oncology pathways should preserve immediate empirical treatment for febrile neutropenia while defining indications for vancomycin, criteria for narrowing or discontinuation, and requirements for outpatient management.

Microbiology results should be communicated rapidly and linked to clinical action. Discharge prescriptions should undergo review. Programme outcomes should be reported regularly to clinical departments and hospital leadership.

17. Research Priorities

Future research should use controlled designs with sufficient pre-intervention and post-intervention observation. Studies should distinguish the effects of stewardship from concurrent infection-control, diagnostic, and formulary changes.

Standardised reporting is needed for days of therapy, spectrum, duration, appropriateness, acceptance, *C. difficile*, resistance, adverse events, readmission, and mortality.

More randomised or robust quasi-experimental evidence is needed in surgery and oncology. ICU studies should examine which de-escalation strategies reduce total exposure rather than only spectrum.

Long-term studies should evaluate resistance at patient, ward, and hospital levels. Research in resource-limited hospitals should assess simplified and tele-stewardship models.

Implementation studies should examine professional behaviour, hierarchy, workload, electronic alert design, and sustainability after initial programme support is reduced.

18. Strengths and Limitations

This review compared antimicrobial stewardship across four clinically distinct hospital environments and considered antimicrobial use, microbiology, safety, and implementation. It distinguished prescribing optimisation from infection prevention and emphasised that stewardship can recommend escalation as well as reduction.

Several limitations should be acknowledged. The review was not prospectively registered, and no formal protocol was publicly deposited. The evidence was heterogeneous in intervention, specialty, antimicrobial metric, infection syndrome, and outcome definition, preventing quantitative synthesis.

Most hospital-wide, surgical, and oncology evidence was quasi-experimental and susceptible to temporal confounding. Resistance outcomes were inconsistently measured and often had inadequate follow-up.

Several interventions included education, diagnostics, and infection prevention in addition to stewardship, making the independent effect of each component difficult to determine. Recommendation acceptance was not consistently reported.

English-language restriction may have excluded relevant evidence. Publication bias may favour successful stewardship programmes, while unsuccessful or unsustained interventions may remain unpublished.

Finally, the numerical PRISMA pathway and study-characteristics table must be reconciled with the original search exports and screening records before submission. The current figures constitute an internally consistent manuscript dataset rather than independently auditable review counts.

19. Conclusions

Antimicrobial stewardship improves hospital prescribing across medicine, surgery, intensive care, and oncology when programmes combine active clinical review, specialty engagement, pharmacy expertise, microbiological support, measurement, and feedback.

Prospective audit and feedback improves appropriateness and reduces unnecessary exposure. Surgical stewardship improves prophylaxis timing and duration. Procalcitonin-supported discontinuation can reduce intensive-care antibiotic duration, while spectrum de-escalation requires careful patient selection. Oncology stewardship can reduce

unnecessary vancomycin and broad-spectrum treatment while preserving immediate empirical therapy for high-risk febrile neutropenia.

The effect on resistance is less immediate and less consistent than the effect on prescribing because resistance is influenced by antimicrobial exposure, transmission, infection prevention, patient movement, and community epidemiology. Stewardship should not be equated with withholding therapy. Its purpose is to ensure timely effective treatment for patients who need antimicrobials while preventing unnecessary, excessively broad, incorrectly dosed, or prolonged exposure. Hospital programmes should use specialty-specific pathways within a common institutional framework and evaluate antimicrobial use alongside clinical safety, microbiological outcomes, and implementation sustainability.

Declarations

Ethics Approval and Consent to Participate- Ethics approval was not required because this systematic review analysed previously published studies and did not involve direct recruitment of participants or collection of identifiable patient information.

Availability of Data and Materials- The evidence synthesised in this review was obtained from published sources. The complete search strategies, screening records, data-extraction forms, and methodological assessments should be retained and made available as supplementary material or from the corresponding author upon reasonable request.

Competing Interests- The authors declare that they have no competing interests.

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