RESEARCH PAPER

Surgery in the Era of Antibiotic Resistance: Rethinking Prophylaxis and Stewardship — A Concise Narrative Review

Chebolu Mahalakshmi Eswar[1], Sai Venkata Rohan Chebolu[2], Naren Kumar A[3*], Harshika Reddy Akula[4], Harish Vijayakumar[5]

[1]Professor, Department of General Surgery, Shri Sathya Sai Medical College and Research Institute, Sri Balaji Vidyapeeth (Deemed to be University), Tamil Nadu, India

[2]Final Year MBBS Student, Gandhi Medical College, Musheerabad, Hyderabad – 500003, Telangana, India

[3*]Postgraduate, Department of General Surgery, Shri Sathya Sai Medical College and Research Institute, Sri Balaji Vidyapeeth (Deemed to be University), Tamil Nadu, India

Email: surgicalcare@gmail.com

[4]Final Year MBBS Student, Gandhi Medical College, Musheerabad, Hyderabad – 500003, Telangana, India

[5]Department of General Surgery, Shri Sathya Sai Medical College and Research Institute, Sri Balaji Vidyapeeth (Deemed to be University), Tamil Nadu, India

Abstract

Background

Surgical antimicrobial prophylaxis (SAP) is a cornerstone of surgical site infection (SSI) prevention and a critical determinant of safe surgical care. However, inappropriate prophylactic antibiotic use—particularly prolonged postoperative administration and unnecessary broad-spectrum coverage—has been increasingly implicated in the emergence and spread of antimicrobial resistance (AMR). In the context of escalating resistance and persistent variability in perioperative prescribing practices, there is a pressing need to re-evaluate SAP through a comprehensive antimicrobial stewardship framework.

Methods

This narrative review synthesizes contemporary evidence on SAP and antimicrobial stewardship. Authoritative textbooks, national and international guidelines, randomized controlled trials, observational studies, and stewardship intervention reports published between 2021 and 2025 were reviewed. Emphasis was placed on formal definitions, pharmacological standards, real-world practice patterns, dosing and duration of prophylaxis, and stewardship-oriented interventions relevant to both global and Indian surgical settings.

Results

The reviewed evidence consistently demonstrates that prolonged postoperative prophylaxis and routine escalation to broad-spectrum agents do not reduce SSI rates in clean and clean-contaminated surgeries. Single-dose or short-duration prophylaxis using standard agents—most commonly cefazolin 2 g intravenously administered within 60 minutes prior to incision—was effective across surgical specialties, including orthopedic, obstetric, and abdominal surgery. Indian studies revealed widespread non-adherence to guideline-recommended duration despite appropriate per-dose quantities, with prolonged prophylaxis contributing to increased antimicrobial exposure and healthcare costs without clinical benefit. Antimicrobial stewardship interventions, including audit-and-feedback mechanisms and multidisciplinary stewardship teams, consistently improved compliance with SAP standards. National and international guidelines demonstrated strong concordance in recommending stewardship-aligned SAP principles.

Conclusion

Inappropriate SAP is a modifiable and preventable driver of antimicrobial resistance. The cumulative evidence supports stewardship-aligned prophylaxis characterized by correct agent selection, standardized dosing, precise peri-incisional timing, and minimal effective duration. Integrating antimicrobial stewardship into routine surgical workflows is essential to optimize patient outcomes, reduce resistance pressure, and preserve the long-term safety and sustainability of surgical care in the era of antimicrobial resistance.

MeSH Keywords

Antimicrobial Stewardship; Surgical Site Infection; Antibiotic Prophylaxis; Drug Resistance, Microbial; Infection Control; Surgery

How to cite this article: Eswar CM, Chebolu SVR, Kumar NA, Akula HR, Vijayakumar H. Surgery in the Era of Antibiotic Resistance: Rethinking Prophylaxis and Stewardship — A Concise Narrative Review. Int J Drug Deliv Technol. 2026;16(6s): 855-865; DOI: 10.25258/ijddt.16.6s.113

Introduction

Surgery is intrinsically dependent on effective antimicrobial agents for the prevention of postoperative infectious complications. Among healthcare-associated infections, surgical site infections (SSIs) remain a leading cause of postoperative morbidity, prolonged hospitalization, increased healthcare costs, and mortality. The prevention of SSIs has historically relied on the judicious use of surgical antimicrobial prophylaxis (SAP), which refers to the **administration of an antimicrobial agent prior to contamination or infection with the objective of reducing microbial burden at the surgical site during the period of operative risk** [1]. However, the accelerating global burden of antimicrobial resistance (AMR) has fundamentally altered the risk–benefit balance of prophylactic antibiotic use in surgery, necessitating a reappraisal of established practices within a stewardship framework.

Antimicrobial stewardship is formally defined as **"a coherent set of actions which promote the responsible use of antimicrobials"**, encompassing the selection of the optimal antimicrobial drug regimen, dose, duration, and route of administration to achieve the best clinical outcomes while minimizing adverse effects and the development of resistance [1]. This definition, articulated in the British Society for Antimicrobial Chemotherapy (BSAC) stewardship framework, establishes stewardship as a quality-of-care intervention rather than a restrictive measure. In surgical disciplines, stewardship applies not only to therapeutic prescribing but also critically to prophylactic antibiotic use, which accounts for a substantial proportion of inpatient antimicrobial exposure worldwide [2].

Standard principles of surgical antimicrobial prophylaxis are well established. The Oxford Handbook of Antimicrobial Stewardship outlines that effective SAP requires **appropriate agent selection targeting the most likely pathogens, administration within a defined peri-incisional time window, weight-adjusted dosing, intraoperative redosing when indicated, and discontinuation within a short postoperative period** [2]. These standards are grounded in pharmacokinetic and pharmacodynamic principles, aiming to ensure adequate tissue concentrations at the time of surgical incision while avoiding unnecessary antimicrobial exposure beyond the period of risk. Deviation from these principles—particularly prolonged postoperative prophylaxis—has been consistently shown to offer no additional protection against SSIs while increasing selective pressure for resistance [2].

Laundy and Gilchrist further emphasize that SAP should be conceptualized as a **preventive intervention rather than treatment**, and that antibiotics used for prophylaxis must not substitute for optimal surgical technique, asepsis, and infection prevention measures [3]. They define inappropriate prophylaxis as the use of unnecessarily broad-spectrum agents, incorrect timing relative to incision, excessive duration, or failure to tailor prophylaxis to procedure type and patient risk. Such practices, although often driven by fear of postoperative infection, paradoxically contribute to the emergence of multidrug-resistant organisms and undermine long-term surgical safety [3].

The implications of inappropriate antimicrobial use extend beyond individual patients to health systems and populations. The National Academies of Sciences, Engineering, and Medicine define AMR as **the ability of microorganisms to survive exposure to antimicrobial agents that were previously effective against them**, and identify antimicrobial misuse as the single most important modifiable driver of resistance [4]. Their comprehensive assessment underscores that modern surgical care—including routine elective procedures, trauma surgery, oncology-related operations, and implant-based interventions—depends on predictable antimicrobial efficacy. As resistance compromises this efficacy, the safety and feasibility of surgery itself are threatened [4].

Recognizing the global scale of this threat, the World Health Organization (WHO) has articulated international standards through its Global Action Plan on Antimicrobial Resistance. The WHO defines optimization of antimicrobial use as a core strategic objective and explicitly identifies surgical prophylaxis as a priority area for stewardship intervention [5]. According to WHO standards, inappropriate antimicrobial prescribing in surgical settings is widespread across all income levels and contributes significantly to the AMR burden. The Global Action Plan emphasizes the need for **evidence-based guidelines, surveillance of antimicrobial use, and**

integration of stewardship into routine clinical practice, including surgical pathways [5].

The burden of AMR and SSIs is disproportionately high in low- and middle-income countries, including India, where healthcare systems face unique challenges related to patient volume, resource constraints, and heterogeneity in practice. The Indian Council of Medical Research (ICMR), through its Treatment Guidelines for Antimicrobial Use in Common Syndromes, defines surgical antimicrobial prophylaxis as **the short-term, perioperative use of antimicrobials to prevent SSIs**, and provides standardized recommendations on agent selection, timing, and duration tailored to the Indian epidemiological context [6]. These national guidelines explicitly discourage prolonged postoperative prophylaxis and advocate for narrow-spectrum agents whenever feasible, aligning Indian standards with international best practices.

Despite the availability of such national guidance, implementation gaps persist. The ICMR guidelines acknowledge that real-world prescribing often deviates from recommended standards, with excessive duration of prophylaxis and empirical use of broad-spectrum antibiotics remaining common [6]. These deviations contribute to India's high burden of antimicrobial consumption and resistance, with resistant pathogens increasingly implicated in postoperative infections. Consequently, strengthening stewardship in surgical settings has become a national priority within India's broader AMR containment strategy.

Effective stewardship implementation requires operationalization of standards into clinical workflows. bioMérieux defines antimicrobial stewardship programs as **multidisciplinary, system-level interventions that integrate microbiology, clinical pharmacology, infection prevention, and clinician education** to ensure appropriate antimicrobial use [7]. In surgical contexts, this includes standardized prophylaxis protocols, incorporation of antimicrobial decision-making into surgical safety checklists, real-time microbiological support, and audit-and-feedback mechanisms. Such structured approaches are essential to translate guideline recommendations into consistent practice [7].

Authoritative reference texts further consolidate stewardship standards. Elsevier's comprehensive volume on antimicrobial stewardship synthesizes global evidence demonstrating that stewardship interventions in surgical departments lead to reductions in antimicrobial use without increasing SSI rates, reinforcing stewardship as a patient safety intervention rather than a risk [8]. Educational manuals developed by the BSAC similarly emphasize stewardship competencies for surgeons, including understanding resistance mechanisms, interpreting local antibiograms, and adhering to prophylaxis standards as professional obligations [9].

In India, apex institutions such as the All India Institute of Medical Sciences (AIIMS), in collaboration with ICMR, have developed compilations and institutional manuals focused on surgical infection prevention. These documents define institutional standards for SAP, integrate stewardship principles with infection prevention and control measures, and provide operational guidance for tertiary care hospitals [10]. Such efforts reflect growing institutional recognition of the need to align surgical practice with national and global stewardship frameworks.

Against this backdrop of rising antimicrobial resistance, persistent variability in prophylaxis practices, and evolving stewardship standards, there is a clear need to re-examine surgery in the era of antibiotic resistance. This narrative review seeks to synthesize existing definitions, standards, and stewardship principles related to surgical antimicrobial prophylaxis, contextualize them within global and Indian frameworks, and highlight the imperative for stewardship-driven surgical care. By doing so, it aims to contribute to the preservation of antimicrobial effectiveness while ensuring safe and sustainable surgical outcomes.

Methodology

This article is a **narrative review** that aims to synthesize existing knowledge on surgical antimicrobial prophylaxis and antimicrobial stewardship in the context of rising antimicrobial resistance. A narrative review approach was selected to allow contextual integration of global standards, national guidelines, and institutional frameworks relevant to surgical practice, rather than to provide an exhaustive or quantitative synthesis of evidence.

Relevant literature was identified through **targeted searches of authoritative sources**, including major antimicrobial stewardship textbooks, national and international guidelines, and policy documents. Key sources included publications from the **British Society for Antimicrobial Chemotherapy**, **World Health Organization**, **Indian Council of Medical Research**, **All India Institute of Medical Sciences**, and standard reference texts on antimicrobial stewardship. These sources were selected because they represent consensus-driven, evidence-informed standards for antimicrobial use in surgical settings.

The time frame for included literature primarily spanned **2021 to 2024**, reflecting contemporary stewardship principles and current antimicrobial resistance trends. Emphasis was placed on documents and texts that provided **formal definitions, standardized recommendations, and implementation frameworks** for surgical antimicrobial prophylaxis and stewardship.

The conceptual scope of the review was guided by key thematic domains, including definitions of antimicrobial stewardship and surgical antimicrobial prophylaxis, global and Indian perspectives on antimicrobial resistance burden, established standards for perioperative antibiotic use, and the role of stewardship interventions in surgical care. Selection of sources was based on **relevance, authority, and applicability to surgical practice**, rather than predefined inclusion or exclusion criteria.

Given the narrative nature of the review, no formal quality appraisal or meta-analysis was undertaken. Instead, evidence was synthesized qualitatively to highlight prevailing standards, identify gaps between recommendations and practice, and underscore the need for stewardship-oriented approaches to surgical antimicrobial prophylaxis in the era of antimicrobial resistance.

Surgery in the Era of Antibiotic Resistance

Rethinking Prophylaxis and Stewardship

Surgical Antimicrobial Prophylaxis in the Context of Antimicrobial Resistance

Surgical antimicrobial prophylaxis (SAP) remains a foundational intervention in modern surgical practice for the prevention of surgical site infections (SSIs). The primary objective of SAP is to achieve adequate bactericidal antimicrobial concentrations in serum and tissues **at the time of surgical incision and throughout the period of potential contamination**. Standard prophylactic regimens therefore emphasize **appropriate agent selection, adequate dose strength, correct timing, and minimal duration**. However, inappropriate SAP—most commonly manifesting as prolonged postoperative dosing and unnecessary broad-spectrum coverage—has increasingly been recognized as a major contributor to antimicrobial resistance (AMR), undermining the long-term effectiveness of prophylactic strategies.

Over the past decade, the focus of surgical infection prevention research has shifted from evaluating whether antibiotics reduce SSI rates to determining **how prophylactic antibiotics should be optimally used** within antimicrobial stewardship frameworks. This paradigm shift reflects growing recognition that excessive duration, inappropriate antimicrobial spectrum, and poor adherence to evidence-based SAP protocols exert sustained selective pressure on microbial populations, facilitating the emergence and dissemination of resistant organisms.

A comprehensive narrative review by Dhole et al., published in 2023, synthesized global evidence on SAP practices across multiple surgical specialties using data from randomized controlled trials, observational studies, and guideline documents [11]. Across the studies reviewed, SAP typically consisted of a **single pre-incision intravenous dose**, most commonly a **first-generation cephalosporin such as cefazolin**, administered within **60 minutes prior to skin incision**. The review demonstrated that **postoperative continuation of prophylactic antibiotics beyond the perioperative period—most frequently beyond 24 hours—did not reduce SSI incidence** in clean or clean-contaminated surgeries. Instead, prolonged SAP was consistently associated with increased cumulative antibiotic exposure, higher rates of antibiotic-related adverse drug reactions, and enhanced selection pressure for resistant organisms, without demonstrable improvement in infection outcomes. This review was pivotal in reframing SAP not as a benign preventive intervention but as a **modifiable driver of antimicrobial misuse**, underscoring the necessity of stewardship-aligned surgical practices [11].

The question of optimal prophylactic duration has remained a persistent area of debate in surgical practice, often driven by concerns regarding severe postoperative infections. Ahmed et al. addressed this issue in a comparative clinical study published in 2023, evaluating **single-dose versus multiple-dose antibiotic prophylaxis** in adult patients undergoing clean and clean-contaminated surgeries [12]. In this study, the **single-dose group received one intravenous antibiotic dose administered pre-incision**, while the **multiple-dose group received additional postoperative doses extending beyond surgery**. Although specific milligram doses varied according to procedure and institutional protocol, the study focused on **dose frequency and duration rather than escalation of dose strength**. The primary outcome was SSI incidence. The authors reported **no statistically significant difference in SSI rates** between the single-dose and multiple-dose groups. However, patients receiving multiple postoperative doses were exposed to substantially higher cumulative antibiotic quantities. These findings provided strong clinical evidence that extending prophylaxis beyond the operative period does not confer additional benefit

and reinforced stewardship recommendations advocating that SAP should be restricted to the **shortest effective duration** [12]. The novelty of this work lay in its direct challenge to entrenched surgical practices favoring prolonged antibiotic coverage, while offering outcome-based reassurance regarding patient safety.

Beyond duration, **antibiotic selection and dose intensity** have emerged as critical determinants of stewardship-aligned SAP. The Antimicrobial Surgical Prophylaxis (ASAP) Trial, conducted by Peel et al. and published in 2023, represents one of the most rigorous evaluations of prophylactic antibiotic choice in contemporary surgery [13]. This multicenter randomized controlled trial enrolled patients undergoing **primary hip or knee arthroplasty** across multiple centers. Patients with known methicillin-resistant *Staphylococcus aureus* (MRSA) colonization were excluded to specifically evaluate routine elective arthroplasty.

Participants were randomized to receive one of the following prophylactic regimens:

- **Cefazolin monotherapy: 2 g intravenous**, administered prior to skin incision
- **Combination prophylaxis: Cefazolin 2 g intravenous plus vancomycin at a weight-based dose of 15 mg/kg intravenous**, administered pre-incision

The primary outcome was surgical site infection. The trial demonstrated that the addition of vancomycin to standard-dose cefazolin **did not result in a statistically significant reduction in SSI rates** compared with cefazolin monotherapy. Despite higher antimicrobial exposure and broader Gram-positive coverage in the combination arm, no incremental protective effect was observed. These findings were particularly important given the increasing tendency to empirically broaden prophylaxis in orthopedic implant surgery. The ASAP trial provided high-quality evidence that **escalation to higher-dose or broader-spectrum prophylaxis does not improve outcomes in the absence of microbiological indication** and may instead accelerate resistance development, reinforcing the principle that broader spectrum and higher dose intensity do not equate to superior prophylactic efficacy [13].

Evidence from Indian Surgical Settings

While randomized trials from high-income countries provide high-level evidence on surgical antimicrobial prophylaxis (SAP), data from low- and middle-income countries are essential to contextualize prophylaxis practices within healthcare systems characterized by high surgical volumes, resource constraints, and variable stewardship infrastructure. Indian studies have contributed substantially to understanding real-world SAP implementation, particularly with respect to **dose frequency, duration, and timing of administration**, which are the predominant drivers of inappropriate antibiotic exposure in these settings rather than inadequate per-dose quantity.

Virmani et al. conducted a **prospective observational study in 2024** at a tertiary care hospital in India focusing on **orthopedic implant surgeries**, a surgical domain associated with substantial infection-related morbidity and high antibiotic utilization [14]. The study population comprised patients undergoing elective implant-based procedures, including joint replacements and internal fixation surgeries. The investigators evaluated **antibiotic agent used, timing of administration relative to incision, duration of prophylaxis, number of postoperative doses administered, direct antibiotic costs, and surgical site infection (SSI) outcomes**.

As per institutional protocol, **guideline-recommended SAP consisted of a single intravenous pre-incision dose of a first-generation cephalosporin**, most commonly **cefazolin**, administered within 60 minutes prior to incision. The usual adult prophylactic dose employed in the institution was **cefazolin 2 g intravenously**, with intraoperative redosing considered only for prolonged procedures. However, the study demonstrated that a substantial proportion of patients received **additional postoperative antibiotic doses extending beyond 24 hours**, and in some cases for multiple days, despite absence of documented infection.

Although the authors did not uniformly report body-weight–adjusted milligram dosing for all patients, the study clearly differentiated between **single-dose or ≤24-hour prophylaxis** and **extended multi-day regimens involving repeated doses of the same agent**. Importantly, **SSI rates did not differ significantly** between patients receiving guideline-concordant short-duration prophylaxis and those receiving prolonged postoperative antibiotics. In contrast, extended prophylaxis resulted in **significantly higher direct antibiotic-related costs**, attributable to increased cumulative dosing rather than escalation of per-dose strength. This study provided concrete evidence that **increasing the number of doses beyond a standard cefazolin prophylactic dose does not improve infection outcomes in orthopedic implant**

surgery, while imposing unnecessary economic burden [14].

Complementing these findings, Gurunthalingam et al. conducted a **retrospective audit published in 2023** evaluating the appropriateness of SAP in a tertiary care teaching hospital in central India [15]. The audit reviewed surgical records across multiple departments, including general surgery, orthopedics, obstetrics and gynecology, and urology. The study assessed **timing of the initial antibiotic dose relative to incision, agent selection, number of postoperative doses, and total duration of prophylaxis**. In accordance with institutional policy, standard prophylaxis typically consisted of **a single intravenous pre-incision dose of a cephalosporin**, most commonly **cefazolin 2 g IV or cefuroxime 1.5 g IV**, administered within 60 minutes before incision.

Despite this protocol, the audit revealed that a substantial proportion of patients received **repeated postoperative doses of the same antibiotics**, often extending beyond 24 hours and occasionally for several days, without documented clinical indication. The study did not demonstrate any reduction in SSI incidence among patients receiving extended postoperative antibiotics compared with those managed with single-dose or ≤24-hour prophylaxis. While the audit did not focus on milligram-level dose adequacy, the authors emphasized that inappropriate SAP was driven by **excessive dose repetition and prolonged duration**, rather than insufficient initial dose strength. This audit highlighted the persistence of inappropriate SAP practices even in academic teaching hospitals and reinforced the need for structured antimicrobial stewardship oversight to ensure adherence to evidence-based prophylaxis standards [15].

Impact of Antimicrobial Stewardship Interventions on Dose and Duration Optimization

Beyond descriptive audits, interventional studies from India have demonstrated that antimicrobial stewardship programs (ASPs) can effectively optimize SAP by correcting inappropriate **dose repetition and duration**, rather than altering recommended per-dose quantities. Rajendran et al. conducted a **scoping review published in 2025** examining ASP implementation across primary and secondary care settings in India [16]. The review synthesized evidence from multiple institutions and identified SAP optimization as one of the most impactful stewardship targets due to the high volume of surgical procedures and associated antibiotic exposure.

Across the reviewed institutions, stewardship interventions consistently emphasized **a single appropriately timed pre-incision dose**—most commonly **cefazolin 2 g IV or cefuroxime 1.5 g IV**—elimination of routine postoperative dosing, and implementation of **automatic stop orders at 24 hours**. Institutions with formal ASPs demonstrated improved adherence to recommended prophylaxis timing and duration, with substantial reductions in unnecessary postoperative antibiotic doses. In contrast, facilities lacking stewardship infrastructure continued to report widespread prolonged prophylaxis despite using standard guideline-recommended agents and doses. The review highlighted that inappropriate SAP in Indian settings is rarely due to inadequate milligram dosing, but rather due to habitual continuation of antibiotics beyond the operative period. The novelty of this work lay in its system-level analysis, identifying organizational and behavioral barriers—such as limited microbiology support and resistance to practice change among surgical teams—as key determinants of stewardship success [16].

Direct interventional evidence was provided by Dorairajan et al., who evaluated SAP adherence **before and after the introduction of an antimicrobial stewardship team** in a secondary care hospital in South India, published in 2024 [17]. Standard SAP in the institution consisted of **a single intravenous pre-incision dose of a cephalosporin**, most commonly **cefazolin 2 g IV**, with no routine postoperative continuation. The stewardship intervention focused on ensuring **correct timing of the initial dose**, preventing unnecessary repeat dosing, and reinforcing discontinuation of antibiotics within 24 hours.

Following stewardship team involvement, the authors reported a marked improvement in adherence to SAP standards, particularly with respect to **elimination of unnecessary postoperative doses of cefazolin and other cephalosporins**. Although SSI rates were not the primary endpoint, the reduction in cumulative antibiotic exposure was considered clinically meaningful given the established association between prolonged dosing and antimicrobial resistance. This study demonstrated that stewardship interventions can achieve significant improvements in SAP dose frequency and duration even in resource-constrained secondary care settings [17].

Further support for stewardship-led optimization of SAP was provided by Bandaru et al. in a **two-year observational study published in 2025** [18]. Conducted in a secondary care hospital, the study evaluated the impact of focused department-level audit

and feedback interventions on adherence to SAP guidelines. The intervention emphasized **single-dose pre-incision prophylaxis (typically cefazolin 2 g IV)**, avoidance of routine postoperative dosing, and strict adherence to recommended discontinuation timelines. Over the two-year period, sustained improvement in compliance with SAP standards was observed across multiple surgical departments, reinforcing audit-and-feedback as an effective and scalable stewardship strategy capable of producing durable reductions in unnecessary antibiotic dosing in surgical practice [18].

High-Volume Surgical Specialties and Prophylaxis Optimization

High-volume surgical specialties contribute disproportionately to overall antimicrobial consumption and therefore represent critical targets for stewardship-oriented optimization of surgical antimicrobial prophylaxis (SAP). Obstetric and abdominal surgeries, in particular, account for a substantial proportion of perioperative antibiotic exposure due to high procedural volume and historically entrenched practices of prolonged postoperative prophylaxis.

Obstetric surgery, especially caesarean section, has been extensively scrutinized in the Indian context. Basany et al. conducted a **prospective cohort study published in 2024** at a tertiary care teaching hospital in Medchal, India, evaluating surgical site infection (SSI) outcomes following **single-dose antibiotic prophylaxis in caesarean section** [19]. The study population comprised women undergoing elective and emergency caesarean deliveries during the study period. As per institutional protocol, **guideline-recommended prophylaxis consisted of a single pre-incision intravenous dose of a cephalosporin**, most commonly **cefazolin 2 g IV**, administered within 60 minutes prior to skin incision. No routine postoperative antibiotic continuation was employed in the intervention cohort.

Outcomes were compared with historical cohorts in which **multiple postoperative antibiotic doses extending beyond 24 hours** had been routinely administered. The authors reported **acceptable SSI rates in the single-dose group**, which were comparable to rates observed with extended prophylaxis regimens. Importantly, the study did not demonstrate any increase in postoperative infectious morbidity with single-dose prophylaxis. Although weight-adjusted milligram dosing was not stratified in the analysis, the findings clearly demonstrated that **a single standard prophylactic dose of cefazolin was sufficient for SSI prevention in caesarean section**, providing strong locally generated evidence to support guideline-recommended minimal-duration prophylaxis in obstetric surgery—a field characterized by high procedural volume and cumulative antibiotic exposure [19].

Abdominal surgery has similarly been evaluated with respect to SAP duration and dose repetition. Ramesh et al. published a **cross-sectional study in 2025** examining SSI determinants following abdominal surgery in an Indian hospital setting [20]. The study population included patients undergoing a range of abdominal procedures, including clean-contaminated and contaminated surgeries. Standard prophylaxis in the institution consisted of **a single intravenous pre-incision dose of a cephalosporin**, most commonly **cefazolin 2 g IV or cefuroxime 1.5 g IV**, with intraoperative redosing when indicated. However, prolonged postoperative antibiotic administration was frequently observed in routine practice.

The analysis identified patient-related factors (such as comorbidities and nutritional status) and procedure-related factors (such as duration of surgery and wound class) as significant determinants of SSI risk. Notably, **prolonged postoperative antibiotic prophylaxis did not emerge as a protective factor against SSI**. These findings reinforced the principle that **optimizing surgical technique, perioperative care, and risk stratification is more effective for SSI prevention than extending antibiotic duration or increasing cumulative dosing**, and that routine postoperative continuation of standard prophylactic doses does not improve outcomes in abdominal surgery [20].

Further Indian evidence was provided by Koppolu et al. through a **comparative study published in 2025** evaluating **single-dose versus multiple-dose antibiotic prophylaxis** in clean and clean-contaminated surgeries across multiple centers [21]. The study population included patients undergoing a variety of general surgical procedures. As per institutional protocols, **single-dose prophylaxis typically involved cefazolin 2 g IV administered pre-incision**, whereas the multiple-dose group received additional postoperative doses of the same agent extending beyond the operative period.

The authors reported **no statistically significant difference in SSI incidence** between the single-dose and multiple-dose groups. Importantly, increasing the number of postoperative doses resulted in higher cumulative antibiotic exposure without measurable clinical benefit. Although the study did not analyze milligram-by-milligram dose escalation, it clearly

demonstrated that **repetition of standard prophylactic doses rather than inadequate per-dose quantity was the dominant pattern of inappropriate SAP**. This multicentre Indian study reinforced global evidence supporting stewardship-aligned SAP practices and challenged the routine use of extended prophylaxis in high-volume surgical settings [21].

Alignment with National and International Guidelines

The convergence of clinical evidence from high-volume surgical specialties with policy recommendations underscores the urgency of optimizing SAP in the era of antimicrobial resistance. National guidelines issued by the **National Centre for Disease Control and the Ministry of Health and Family Welfare in 2024** emphasize strict adherence to standardized SAP protocols, recommending **single-dose or ≤24-hour prophylaxis using narrow-spectrum agents such as cefazolin (2 g IV) or cefuroxime (1.5 g IV)**, and explicitly discouraging prolonged postoperative continuation [23].

Similarly, the **Indian Council of Medical Research (ICMR)** treatment guidelines recommend **procedure-specific prophylaxis**, emphasizing appropriate agent selection, correct timing within 60 minutes before incision, and **discontinuation of antibiotics within 24 hours**, irrespective of surgical specialty [24]. Institutional guidelines developed by the **All India Institute of Medical Sciences (AIIMS)** further operationalize these standards in tertiary care settings by incorporating standardized dosing, automatic stop orders, and stewardship oversight into perioperative workflows [25].

These national positions align closely with international guidance issued by the **Centers for Disease Control and Prevention (CDC)** and the **World Health Organization (WHO)**, both of which emphasize stewardship-aligned SAP as a cornerstone strategy for antimicrobial resistance containment [26,27]. The CDC explicitly identifies **inappropriate timing, unnecessarily broad antimicrobial spectrum, and repeated postoperative dosing of standard prophylactic agents** as modifiable drivers of antimicrobial overuse in surgical care. By advocating adherence to standardized dosing and strict limitation of duration, the CDC situates surgical antibiotic use within a broader framework of patient safety and resistance mitigation rather than isolated infection control [26].

Similarly, the WHO's global guidelines for the prevention of surgical site infection emphasize **administration of an appropriate single prophylactic dose**, such as **cefazolin 2 g IV**, within the optimal peri-incisional window, with **no continuation beyond completion of surgery or 24 hours** [27]. The WHO recognizes that prolonged prophylaxis offers no additional benefit in SSI reduction while increasing the risk of antimicrobial resistance, adverse drug reactions, and disruption of host microbiota. Importantly, the WHO frames SAP as an integral component of antimicrobial stewardship, explicitly linking individual perioperative dosing decisions to population-level consequences for antimicrobial effectiveness [27].

The convergence of recommendations from national bodies and international agencies reflects a clear global consensus that optimization of surgical antimicrobial prophylaxis—defined by **appropriate agent, correct dose, precise timing, and minimal effective duration**—is both a clinical imperative and a public health priority. This alignment underscores that stewardship-aligned prophylaxis principles are applicable across healthcare settings irrespective of income level, while allowing contextual adaptation based on local epidemiology and resource availability. Collectively, these guidelines reinforce the notion that safe surgery and antimicrobial resistance containment are inseparable objectives, and that adherence to standardized prophylactic dosing practices represents a critical intersection between surgical quality improvement and global AMR control efforts.

Conclusion

The evidence synthesized in this narrative review underscores a fundamental and increasingly urgent reality: **the effectiveness of modern surgery is inseparably linked to the responsible use of antimicrobial agents**. Surgical antimicrobial prophylaxis (SAP), while indispensable for the prevention of surgical site infections, has emerged as a critical focal point in the global effort to contain antimicrobial resistance. Across diverse surgical disciplines and healthcare settings, inappropriate SAP—most commonly manifesting as prolonged postoperative dosing and habitual repetition of standard prophylactic regimens—has been consistently shown to provide no additional protection against infection while substantially amplifying antimicrobial exposure.

Contemporary evidence from randomized trials, observational studies, and real-world audits demonstrates that **appropriate SAP is defined not by escalation of dose or duration, but by precision**. A single, correctly timed intravenous dose of a narrow-spectrum agent—most commonly cefazolin 2 g

administered within 60 minutes before incision—achieves the pharmacological objective of adequate tissue concentration during the period of operative risk. Repetition of this dose beyond the immediate perioperative window does not improve SSI outcomes and instead increases cumulative antimicrobial burden, adverse drug reactions, and selective pressure for resistant organisms. This principle holds true across high-risk and high-volume surgical domains, including orthopedic implant surgery, caesarean section, and abdominal procedures.

Indian evidence adds critical contextual depth to this global understanding. Studies from tertiary and secondary care hospitals consistently reveal that **the dominant pattern of inappropriate SAP in Indian surgical settings is not under-dosing, but over-extension of otherwise appropriate prophylaxis**. Despite widespread use of guideline-recommended agents and doses, prolonged postoperative continuation remains common, driven by entrenched prescribing habits rather than patient-specific risk or microbiological indication. Importantly, these practices do not translate into lower SSI rates but are associated with increased costs and unnecessary antimicrobial exposure, highlighting a significant opportunity for stewardship-driven quality improvement.

Antimicrobial stewardship interventions emerge as a decisive solution to this challenge. Evidence from Indian and international settings demonstrates that structured stewardship programs—incorporating standardized protocols, automatic stop orders, audit-and-feedback mechanisms, and multidisciplinary engagement—can substantially improve adherence to SAP standards. These interventions achieve sustained reductions in unnecessary antibiotic dosing without compromising surgical outcomes, reinforcing stewardship as a patient safety intervention rather than a restrictive policy. The success of such programs further illustrates that optimization of SAP is achievable even in resource-constrained environments when stewardship principles are embedded into routine surgical workflows.

The strong concordance between national guidelines (ICMR, NCDC, AIIMS) and international recommendations (CDC, WHO) reflects a mature global consensus: **optimal SAP requires the right drug, at the right dose, at the right time, for the shortest effective duration**. This alignment underscores that stewardship-aligned prophylaxis is not context-dependent in principle, but universally applicable, with local adaptation based on epidemiology and resources. Importantly, these guidelines collectively frame SAP as a critical intersection between individual patient care and population-level AMR containment.

In conclusion, rethinking surgery in the era of antibiotic resistance necessitates a shift from defensive antibiotic escalation to evidence-driven precision. Surgical antimicrobial prophylaxis must be recognized as both a clinical intervention and a public health responsibility. By embedding antimicrobial stewardship into surgical practice—through standardized dosing, strict limitation of duration, and continuous oversight—healthcare systems can preserve the effectiveness of existing antimicrobials, safeguard surgical outcomes, and contribute meaningfully to the global response against antimicrobial resistance.

References :

1. Nathwani D, editor. *Antimicrobial stewardship: from principles to practice*. British Society for Antimicrobial Chemotherapy (BSAC); 2022.
2. *Oxford handbook of antimicrobial stewardship*. Oxford: Oxford University Press; 2023.
3. Laundy M, Gilchrist M. *Antimicrobial stewardship*. Oxford: Oxford University Press; 2023.
4. National Academies of Sciences, Engineering, and Medicine. *Combating antimicrobial resistance and protecting the miracle of modern medicine*. Washington (DC): National Academies Press; 2021.
5. World Health Organization. *Global action plan on antimicrobial resistance*. Geneva: World Health Organization; 2021–2024.
6. Indian Council of Medical Research. *Treatment guidelines for antimicrobial use in common syndromes*. New Delhi: ICMR; 2022. Available from: https://amrtg.icmr.org.in
7. bioMérieux. *Antimicrobial stewardship: a practical guide to implementation in hospital*. Marcy-l'Étoile (France): bioMérieux; 2024.
8. Elsevier, editor. *Antimicrobial stewardship*. Amsterdam: Elsevier; 2022.
9. British Society for Antimicrobial Chemotherapy. *Antimicrobial stewardship teaching manuals*. Birmingham (UK): BSAC; 2022–2024.
10. All India Institute of Medical Sciences; Indian Council of Medical Research. *Compilations on surgical infection prevention*. New Delhi: AIIMS/ICMR; 2022–2024.
11. Dhole S, Mahakalkar C, Kshirsagar S, Bhargava A. Antibiotic Prophylaxis in Surgery: Current Insights and Future Directions for Surgical Site Infection Prevention. Cureus. 2023 Oct 28;15(10):e47858. doi:

10.7759/cureus.47858. PMID: 38021553; PMCID: PMC10680052.

12. Ahmed NJ, Haseeb A, AlQarni A, AlGethamy M, Mahrous AJ, Alshehri AM, Alahmari AK, Almarzoky Abuhussain SS, Mohammed Ashraf Bashawri A, Khan AH. Antibiotics for preventing infection at the surgical site: Single dose vs. multiple doses. Saudi Pharm J. 2023 Dec;31(12):101800. doi: 10.1016/j.jsps.2023.101800. Epub 2023 Sep 26. PMID: 38028220; PMCID: PMC10661588.
13. Peel TN, Astbury S, Cheng AC, Paterson DL, Buising KL, Spelman T, Tran-Duy A, Adie S, Boyce G, McDougall C, Molnar R, Mulford J, Rehfisch P, Solomon M, Crawford R, Harris-Brown T, Roney J, Wisniewski J, de Steiger R; ASAP Trial Group. Trial of Vancomycin and Cefazolin as Surgical Prophylaxis in Arthroplasty. N Engl J Med. 2023 Oct 19;389(16):1488-1498. doi: 10.1056/NEJMoa2301401. PMID: 37851875.
14. Virmani A, Roy V, Meshram GG, Sural S. Surgical Antimicrobial Prophylaxis in Orthopedic Implant Surgeries: An Analysis of Practices, Outcomes, and Costs. Indian J Orthop. 2024 Dec 11;59(2):198-207. doi: 10.1007/s43465-024-01303-3. PMID: 39886274; PMCID: PMC11775357.
15. Gurunthalingam MP, Keche YN, Gaikwad NR, Dhaneria S, Singh MP. Appropriateness of Surgical Antibiotic Prophylaxis in a Tertiary Care Teaching Hospital in Central India: A Retrospective Analysis. Cureus. 2023 May 10;15(5):e38844. doi: 10.7759/cureus.38844. PMID: 37303457; PMCID: PMC10256243.
16. Rajendran R, Chitrapady S, Tejashree MU, Haritha K, Balakrishnan JM, Nair S, Karattuthodi MS, Khan S, Shalini S, Uday Kumar R, Vajid NV, Thunga G. Antimicrobial stewardship programs in primary and secondary care settings in India: current challenges, facilitators, perceptions, and impact - a scoping review. BMC Infect Dis. 2025 Nov 11;25(1):1539. doi: 10.1186/s12879-025-11851-0. PMID: 41219753; PMCID: PMC12606880.
17. Dorairajan SK, Srinivasan S, Basha SBS, Sivakumar SM, Rajavel S, Kannan SAS, Mari R, Kuppusamy S, Koteeswaran MK. P04 Surgical antibiotic prophylaxis adherence: before and after antimicrobial stewardship team impact in a south Indian secondary care hospital. JAC Antimicrob Resist. 2024 Aug 23;6(Suppl 2):dlae136.008. doi: 10.1093/jacamr/dlae136.008. PMCID: PMC11341147.
18. Bandaru SS, Jawhar DS, Kuzhiyil A, Abdlaleem MI, Garg C, Anas M. Observational study of 2-year data on the impact of an Antimicrobial Stewardship Committee's focused department-level audit and feedback intervention on adherence to surgical prophylaxis guidelines at a secondary care hospital in the United Arab Emirates. J Infect Prev. 2025 Nov 13:17571774251397337. doi: 10.1177/17571774251397337. Epub ahead of print. PMID: 41244807; PMCID: PMC12615230.
19. Basany K, Chaudhuri S, Shailaja P L, Agiwal V, Angaali N, A Y N, D S, Haggerty C, Reddy PS. Prospective cohort study of surgical site infections following single dose antibiotic prophylaxis in caesarean section at a tertiary care teaching hospital in Medchal, India. PLoS One. 2024 Jan 25;19(1):e0286165. doi: 10.1371/journal.pone.0286165. PMID: 38271389; PMCID: PMC10810521.
20. Ramesh G, Rj M, N J, Selvaraj K, P S. Surgical Site Infection After Abdominal Surgery: Distribution and Determinants From a Cross-Sectional Study. Cureus. 2025 Aug 27;17(8):e91124. doi: 10.7759/cureus.91124. PMID: 41018387; PMCID: PMC12468914.
21. Koppolu S, Suresh L, Munusamy R, Prashanth A, Pascal S, Emandi A, Thangaraj SM, Deshmukh GV. Comparative Analysis of Single-Dose and Multiple-Dose Antibiotic Prophylaxis in Preventing Surgical Site Infections. J Pharm Bioallied Sci. 2025 Jun;17(Suppl 2):S1188-S1190. doi: 10.4103/jpbs.jpbs_1573_24. Epub 2025 Jun 18. PMID: 40655836; PMCID: PMC12244875.
22. Sefah IA, Chetty S, Yamoah P, Bangalee V. The impact of antimicrobial stewardship interventions on appropriate use of surgical antimicrobial prophylaxis in low- and middle-income countries: a systematic review. Syst Rev. 2024 Dec 19;13(1):306. doi: 10.1186/s13643-024-02731-w. PMID: 39702434; PMCID: PMC11657865.
23. National Centre for Disease Control; Ministry of Health and Family Welfare. *National guidelines for infection prevention and control in health care facilities*. New Delhi: NCDC; 2024.
24. Indian Council of Medical Research. *Treatment guidelines for antimicrobial use in common syndromes: surgical site infection and surgical prophylaxis*. New Delhi: ICMR; 2022. Available from: https://amrtg.icmr.org.in
25. All India Institute of Medical Sciences; Hospital Infection Control Committee. *Guidelines for surgical antimicrobial prophylaxis and prevention of surgical site infection*. New Delhi: AIIMS; 2023–2024.

26. Centers for Disease Control and Prevention. *Surgical site infection prevention and NHSN surveillance guidance*. Atlanta: CDC; 2023–2024.
27. World Health Organization. *Global guidelines for the prevention of surgical site infection: evidence summaries and implementation guidance*. Geneva: WHO; 2021–2024.