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Antimicrobial Resistance Patterns in Postoperative Surgical Site Infections: A Tertiary Care Hospital Analysis

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ABSTRACT

Background: Surgical site infection (SSI) is a leading healthcare-associated infection in tertiary care hospitals, and an increasing share of causative isolates now display multidrug resistance, complicating both perioperative antibiotic prophylaxis and empirical postoperative therapy. Objective: To synthesize tertiary-hospital evidence on the causative organism spectrum, resistance profile, and risk factors of antimicrobial-resistant (AMR) postoperative SSI, and to draw out implications for perioperative prophylaxis protocols and antimicrobial stewardship. Methods: A narrative synthesis of peer-reviewed tertiary-hospital surveillance studies and clinical practice guidelines was conducted; candidate sources were individually verified against publisher, PubMed/MEDLINE, or Crossref-indexed metadata before inclusion and organized thematically into organism/resistance profile, risk factors, and prophylaxis/stewardship implications. Findings: Staphylococcus aureus (including methicillin-resistant S. aureus), Escherichia coli, Klebsiella pneumoniae, and Pseudomonas aeruginosa recur as dominant SSI isolates, with extended-spectrum beta-lactamase production exceeding 50% and carbapenem resistance approaching or exceeding 40% among Gram-negative isolates in several tertiary-hospital series. Prior antibiotic exposure, pre-existing multidrug-resistant organism colonization, prolonged intensive care or hospital stay, major comorbidity such as diabetes, and prolonged operative duration recur as independent predictors of resistant, rather than merely any, postoperative infection. Guideline-based narrow-spectrum, time-limited prophylaxis remains appropriate in aggregate, but stewardship interventions incorporating local resistance surveillance and, for Staphylococcus aureus, preoperative decolonization show the most consistent benefit. Conclusions: Tertiary hospitals should calibrate perioperative prophylaxis and antimicrobial stewardship programs against their own, regularly updated resistance surveillance data, extend stewardship attention specifically to the surgical antibiotic pathway, and evaluate preoperative multidrug-resistant organism screening where colonization has become common among surgical patients.

Keywords: *antimicrobial resistance; surgical site infection; antibiotic prophylaxis; antimicrobial stewardship; multidrug-resistant organisms*

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Introduction

Surgical site infection (SSI) remains one of the most common healthcare-associated infections encountered in tertiary care hospitals, complicating between 2% and 15% of operative procedures depending on wound class, patient comorbidity burden, and institutional infection-control practice. Beyond the direct clinical consequences of delayed wound healing, prolonged hospitalization, reoperation, and excess mortality, SSI has become a sentinel indicator of a broader and increasingly urgent problem: the rising prevalence of antimicrobial resistance (AMR) among the pathogens that cause postoperative wound infection. Multiple tertiary-hospital surveillance studies published in the past several years report that a substantial proportion of SSI isolates - frequently exceeding one-third to one-half - now meet criteria for multidrug resistance, extended-spectrum beta-lactamase (ESBL) production, or carbapenem resistance [1,2,3]. This convergence of two clinical problems, SSI and AMR, has direct implications for the antibiotics chosen for perioperative prophylaxis, the empirical therapy offered when infection is suspected, and the broader antimicrobial stewardship posture of the surgical service.

The causative organism spectrum of SSI has itself shifted in ways that compound the resistance problem. Historically, Staphylococcus aureus - including methicillin-resistant S. aureus (MRSA) - was considered the dominant SSI pathogen, reflecting

its role as a skin and nasal commensal readily inoculated into the surgical wound. Contemporary surveillance from tertiary centers in South Asia, the Middle East, and sub-Saharan Africa increasingly identifies Gram-negative organisms - Escherichia coli, Klebsiella pneumoniae, and Pseudomonas aeruginosa - as co-dominant or even predominant isolates, particularly after abdominal, hepatobiliary, and colorectal procedures where endogenous gut flora seed the wound [4,5,6]. These Gram-negative organisms carry a disproportionate share of the resistance burden: ESBL production among E. coli and K. pneumoniae isolates from SSI series now commonly exceeds 50%, and carbapenem resistance among P. aeruginosa and K. pneumoniae isolates is no longer a rarity even outside specialist intensive care settings [2,6].

A parallel and mechanistically related literature has examined the patient- and procedure-level risk factors that predispose to AMR-specific SSI, as distinct from SSI in general. Prolonged operative duration, prior antibiotic exposure, pre-existing colonization with multidrug-resistant organisms (MDROs), diabetes mellitus, and prolonged intensive care or hospital stay before surgery recur across cohort studies from geographically and economically diverse tertiary hospitals as independent predictors of resistant, rather than susceptible, postoperative infection [7,8,9]. These findings carry direct implications for how perioperative antibiotic prophylaxis is selected and how antimicrobial stewardship programs should be structured around the surgical patient pathway, since a prophylaxis regimen calibrated to locally circulating susceptible organisms will systematically under-treat a wound already colonized with resistant flora.

This case study synthesizes tertiary-hospital evidence on AMR patterns in postoperative SSI, organized around three themes: the causative organism spectrum and its resistance profile; the clinical and procedural risk factors associated with AMR-SSI specifically; and the implications of these patterns for perioperative antibiotic prophylaxis protocols and institutional antimicrobial stewardship. Rather than presenting original single-site surveillance data, this review draws together the published tertiary-hospital literature to characterize recurring patterns and to identify where current prophylaxis and stewardship practice appears misaligned with the resistance landscape it is meant to address.

Methods

This case study is structured as a narrative synthesis of the published tertiary-hospital literature on antimicrobial resistance patterns in postoperative surgical site infection, rather than a single-center primary surveillance study or a formally registered systematic review. Relevant literature was identified through targeted searches combining terms including "surgical site infection," "antimicrobial resistance," "multidrug-resistant organisms," "tertiary care hospital," "surgical antibiotic prophylaxis," "antimicrobial stewardship," and pathogen-specific terms ("MRSA," "extended-spectrum beta-lactamase," "carbapenem-resistant," "Klebsiella," "Pseudomonas aeruginosa"). Candidate sources were restricted to peer-reviewed journal articles and internationally recognized clinical practice guidelines, and each candidate source was individually verified against its publisher record, PubMed/MEDLINE listing, or Crossref-indexed metadata (author list, journal, volume/issue, pagination, and digital object identifier) before inclusion; sources that could not be independently verified in this manner were excluded.

Sources were organized thematically into three domains that structure the Findings section below: (1) the causative organism spectrum and resistance profile of postoperative SSI as reported in tertiary-hospital surveillance series; (2) patient- and procedure-level risk factors specifically associated with AMR-SSI, as distinct from SSI risk in general; and (3) the implications of these patterns for perioperative antibiotic prophylaxis selection and for antimicrobial stewardship program design in surgical services. Because the tertiary-hospital surveillance studies reviewed here differ substantially in surgical case mix, culture and susceptibility-testing methodology, resistance-definition thresholds, and regional AMR epidemiology, no attempt was made to pool reported percentages into a single meta-analytic estimate; figures and tables presented here synthesize illustrative, directionally consistent findings across studies rather than a statistically pooled effect size. This is consistent with the exploratory, cross-institutional nature of a topic in which the clinically relevant conclusion is the recurring pattern across settings rather than a single precise point estimate.

Causative Organisms and Resistance Profiles in Postoperative Surgical Site Infections

Tertiary-hospital surveillance consistently identifies a mixed Gram-positive and Gram-negative organism spectrum in postoperative SSI, with the balance between the two shifting according to surgical specialty and wound class. In a retrospective series of postoperative SSI at an Indian tertiary care centre, S. aureus and P. aeruginosa were the two leading isolates, together accounting for roughly one-third of all recovered organisms, with 33.3% of S. aureus isolates and 37.5% of P. aeruginosa isolates meeting multidrug-resistance criteria [3]. A large retrospective observational study from a Pakistani tertiary hospital similarly documented a mixed organism spectrum with substantial resistance to first-line agents among both Gram-positive and Gram-negative isolates [1]. In Alexandria, Egypt, surveillance of surgical-site infections over a 24-month period found that although the overall SSI incidence was comparatively low (2.3% of surgical patients), the resistance burden among the isolates recovered was severe: 58.7% of Gram-negative isolates were ESBL producers, 45.7% were carbapenem-resistant, and approximately 86% of staphylococcal isolates were methicillin-resistant [2].

Gram-negative predominance is especially pronounced after abdominal, hepatobiliary, and colorectal surgery, reflecting endogenous contamination from gut flora rather than exogenous skin or environmental inoculation. At Tanzania's largest tertiary referral hospital, 77.5% of SSI isolates from general surgical patients were Gram-negative, with P. aeruginosa the single most common organism (16.3%) followed closely by K. pneumoniae and Proteus mirabilis; 63% of all isolates were multidrug-resistant, and ESBL production was documented in over 90% of E. coli isolates [4]. A retrospective cohort of hepatobiliary and pancreatic surgery patients likewise found that nearly half developed SSI, predominantly caused by Gram-negative organisms led by E. coli, with operative duration showing moderate predictive value for infection [5]. Molecular characterization of carbapenem-resistant P. aeruginosa recovered from wound infections at an Egyptian tertiary hospital found that 44.9% of isolates were multidrug-resistant and carbapenem-resistant, with metallo-beta-lactamase genes (blaNDM-1 in 27.3% and blaOXA-48 in 13.6% of resistant isolates) responsible for the carbapenem-resistant phenotype, and genetic

fingerprinting indicating polyclonal rather than single-source transmission - evidence that the resistance burden reflects broad environmental and antibiotic-selection pressure rather than a single containable outbreak [6].

Representative resistance findings among postoperative surgical site infection isolates reported in tertiary-hospital surveillance studies.

Setting (reference)	Predominant organism(s)	Key resistance finding	Notable resistant phenotype
Tertiary hospital, India (Singh et al. 2025)	S. aureus, P. aeruginosa	33.3% of S. aureus and 37.5% of P. aeruginosa isolates multidrug-resistant	MDR S. aureus and P. aeruginosa
Tertiary hospital, Alexandria, Egypt (Raouf et al. 2020)	Gram-negative bacilli, S. aureus	58.7% of Gram-negative isolates ESBL-producing; 45.7% carbapenem-resistant	ESBL and carbapenem-resistant Gram-negatives; ~86% methicillin-resistant S. aureus
Muhimbili National Hospital, Tanzania (Manyahi et al. 2014)	P. aeruginosa, K. pneumoniae, E. coli	63% of isolates multidrug-resistant; >90% of E. coli ESBL-producing	ESBL-producing Enterobacteriaceae
Tertiary hospital, Egypt (El Menofy et al. 2025)	P. aeruginosa (wound isolates)	44.9% of isolates multidrug- and carbapenem-resistant	blaNDM-1 (27.3%) and blaOXA-48 (13.6%) carbapenemase genes
University Teaching Hospitals, Lusaka, Zambia (Siame et al. 2024)	E. coli (rectal carriage, surgical patients)	Overall ESBL E. coli carriage 29.9%, rising from 17.3% preoperatively to 47.9% postoperatively	ESBL-producing E. coli

Colonization with resistant organisms before or during hospitalization appears to be a direct precursor to resistant infection rather than a coincidental finding. A cross-sectional study of hemorrhoidectomy patients in southern China found that 21.1% of patients carried multidrug-resistant Gram-negative bacteria in the rectoanal region preoperatively, and that colonized patients developed SSI at a rate more than twenty-fold higher than non-colonized patients (41.6% versus 1.8%), with rectoanal colonization independently associated with SSI at an adjusted odds ratio exceeding 32 [8]. A comparable surveillance study of rectal ESBL-producing E. coli carriage among surgical patients in Lusaka, Zambia, found an overall carriage prevalence of 29.9%, with carriage nearly tripling from the preoperative to the postoperative period (17.3% to 47.9%) - a pattern consistent with selection pressure exerted by perioperative antibiotic exposure itself [10]. Table 1 summarizes representative resistance findings across several of the tertiary-hospital surveillance studies reviewed here, illustrating both the geographic breadth and the consistency of the underlying pattern: a substantial and, in several series, a rising share of SSI-causing organisms no longer respond reliably to the antibiotic classes traditionally used for surgical prophylaxis or empirical postoperative therapy.

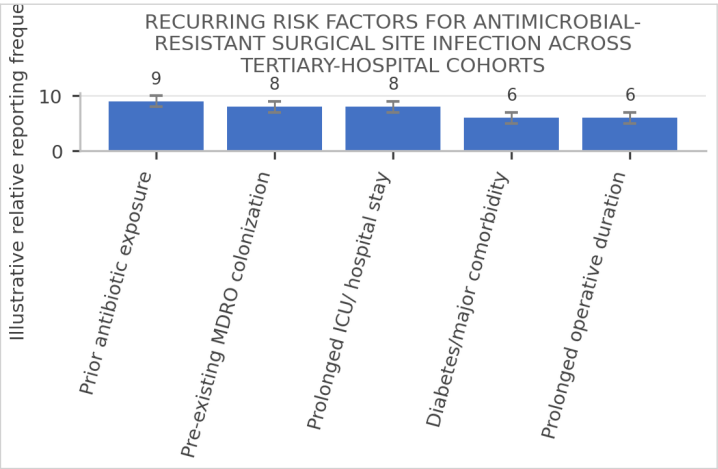
The global significance of this organism-resistance pattern is underscored by the World Health Organization's priority pathogens list for antibiotic-resistant bacteria, which identifies carbapenem-resistant Enterobacteriaceae (including K. pneumoniae and E. coli) and carbapenem-resistant P. aeruginosa among the "critical" priority category for which new antibiotic development is most urgently needed, precisely the organisms recurring across the surgical-site infection surveillance literature reviewed here [11]. MRSA occupies the WHO's "high" priority category, and its persistence as a leading SSI isolate - documented at rates as high as 86% methicillin resistance among staphylococcal wound isolates in the Alexandria series [2] - indicates that Gram-positive resistance has not receded even as Gram-negative resistance has drawn increasing surveillance attention.

Risk Factors for Antimicrobial-Resistant Surgical Site Infection

A distinct body of evidence addresses which patients and which procedural circumstances specifically predict resistant, as opposed to susceptible, postoperative infection - a question with direct relevance to how empirical antibiotic therapy should be selected while culture results are pending. A retrospective study of 2,471 surgical patients at a Romanian tertiary-care center found that prolonged intensive care unit stay and longer overall hospitalization were the principal independent predictors of multidrug-resistant infection, that K. pneumoniae, P. aeruginosa, and Acinetobacter baumannii were the dominant MDR pathogens, and that MDR status was itself an independent predictor of mortality after adjustment for other factors (16.8% versus 4.4% in non-MDR infections) [7]. This finding - that the duration of the hospital and intensive-care exposure preceding infection, rather than any single procedural characteristic, is the dominant driver of resistance - recurs across settings and suggests that the hospital environment itself functions as a reservoir and selection pressure independent of the specific operation performed.

Prior antibiotic exposure and pre-existing MDRO colonization form a second, closely related risk domain. The Zambian rectal ESBL E. coli carriage study noted explicitly that antibiotic use "generally alters the composition of the gut flora, thereby leading to the selection of highly resistant bacteria," consistent with the near-tripling of carriage prevalence observed from the preoperative to postoperative period in that cohort [10]. The hemorrhoidectomy colonization study similarly identified recent multiple antibiotic courses as a factor elevating multidrug-resistant bacterial colonization risk before surgery, which then translated into a markedly elevated SSI rate [8]. Classic risk-factor literature for SSI more broadly - although not resistance-specific - reinforces the plausibility of this pathway: a case-control study of laminectomy patients identified diabetes (odds ratio 4.2) and elevated body mass index (odds ratio 7.1) as independent SSI predictors, both of which are also established correlates of prolonged or repeated antibiotic exposure and of impaired local tissue defense against colonizing organisms [9].

Approximate relative frequency with which patient- and procedure-level factors are reported as independent predictors of antimicrobial-resistant, rather than merely any, postoperative surgical site infection across tertiary-hospital cohort studies reviewed (Ambrosie et al., 2026; Li et al., 2023; Siame et al., 2024; Friedman et al., 2007).



Procedural and operative factors compound these patient-level risks. The foundational National Nosocomial Infections Surveillance System risk-index framework established operative duration exceeding the procedure-specific 75th percentile, wound contamination class, and underlying patient comorbidity (American Society of Anesthesiologists score) as the three principal determinants of SSI risk across surgical specialties, a framework still used to risk-stratify surveillance data more than three decades later [12]. In a Tanzanian cohort at Bugando Medical Centre, prolonged operative duration was identified alongside pre-existing comorbid illness, surgical drain use, and single-agent iodine skin preparation as significant predictors of SSI, in a setting where S. aureus predominated and the overall SSI rate reached 26% [13]. A retrospective cohort study in Kuala Lumpur, Malaysia, spanning 2020-2023 similarly documented a high incidence of multidrug-resistant organisms among SSI isolates alongside a distinct set of modifiable risk factors, reinforcing that both the causative organism spectrum and the associated resistance burden vary systematically with identifiable, and at least partially modifiable, procedural circumstances [14]. In a hospital-wide Ethiopian surveillance series, 79% of SSI-associated bacterial isolates demonstrated multidrug resistance, with S. aureus and E. coli again the leading organisms, underscoring that this risk-factor architecture - comorbidity, procedural duration, and antibiotic exposure history - recurs even in resource-constrained tertiary settings with more limited microbiological surveillance infrastructure [15].

Figure 1 synthesizes the recurring risk factors reported across the tertiary-hospital cohort studies reviewed here, expressed as the approximate relative frequency with which each factor is identified as an independent predictor of resistant, rather than merely any, postoperative infection. Prior antibiotic exposure and pre-existing MDRO colonization emerge as the most consistently reported drivers, followed by prolonged ICU or hospital stay, diabetes and other major comorbidity, and prolonged operative duration - an ordering that has direct implications for how institutions might triage patients for enhanced perioperative precautions or pre-operative screening.

Implications for Perioperative Antibiotic Prophylaxis and Antimicrobial Stewardship

The clinical practice guideline jointly issued by the American Society of Health-System Pharmacists, the Infectious Diseases Society of America, the Surgical Infection Society, and the Society for Healthcare Epidemiology of America remains the reference framework for perioperative antibiotic prophylaxis, recommending administration within 60 minutes before incision (120 minutes for vancomycin or fluoroquinolones), single-dose or short-duration regimens of less than 24 hours for most procedures, and cefazolin as the preferred agent for the majority of clean and clean-contaminated operations on the basis of its established efficacy, favorable pharmacokinetics, and narrow spectrum [16]. The Centers for Disease Control and Prevention's 2017 guideline for the prevention of surgical site infection reinforces this narrow-spectrum, time-limited approach as part of a bundle of evidence-based perioperative measures, explicitly cautioning against prolonging prophylaxis beyond the closure of the incision even in the presence of surgical drains [17]. Both guidelines were developed primarily from trial evidence generated in settings with comparatively low background AMR prevalence, which raises a direct tension for tertiary hospitals now documenting ESBL production in more than half of Gram-negative SSI isolates and carbapenem resistance approaching or exceeding 40% in some series [2,6]: a standard cefazolin-based prophylaxis regimen, however well supported by the aggregate trial evidence, offers no coverage against the resistant organisms that a meaningful share of high-risk patients in these settings are already colonized with before the incision is made.

The trial evidence on prophylaxis duration itself does not, however, support resolving this tension simply by extending or broadening prophylaxis empirically. A recent systematic review and meta-analysis of eleven randomized controlled trials comparing shorter with prolonged systemic perioperative antibiotic prophylaxis in clean orthopedic surgery found no statistically significant additional reduction in SSI with prolonged regimens (relative risk 1.07, 95% CI 0.86-1.34), while prolonged exposure carries the well-documented cost of selecting for resistant flora, as the colonization-dynamics evidence reviewed above illustrates directly [18,10]. A broader systematic review of antimicrobial stewardship interventions targeting surgical antibiotic prophylaxis similarly concluded that stewardship programs most reliably improve compliance with guideline-recommended antibiotic choice, dose, and duration, but that timing compliance and downstream SSI rates are more variable across studies, suggesting that guideline compliance alone is an incomplete lever unless paired with locally calibrated choice of agent [19].

Institutional stewardship interventions that incorporate local resistance surveillance directly into prophylaxis and treatment protocols show more consistent benefit than duration-focused interventions alone. A quasi-experimental study at a Ghanaian teaching hospital found that educational workshops and audit-and-feedback interventions significantly improved compliance with antibiotic choice ($p = 0.001$) and duration ($p < 0.001$) for surgical prophylaxis, reduced overall antibiotic consumption, and did so without any observed increase in SSI rates or length of hospital stay - direct evidence that stewardship-driven prophylaxis optimization need not trade infection control for resistance control [20]. A recent narrative review of antibiotic stewardship in surgical departments similarly argues that surgical services have historically been underserved by stewardship programs relative to medical and intensive-care services, despite surgical prophylaxis and treatment together

accounting for a large share of total inpatient antibiotic use, and identifies diagnostic stewardship (including biomarker-guided duration decisions) and multidisciplinary teams incorporating surgeons, pharmacists, and microbiologists as priorities for closing this gap [21]. Table 2 summarizes the principal stewardship and prophylaxis-optimization interventions described across the literature reviewed here, alongside their reported effect on resistance-relevant outcomes and their documented limitations.

Preoperative screening for MDRO colonization represents a further, more targeted implication of the resistance patterns described above, though the evidence base for its routine tertiary-hospital implementation remains less mature than for nasal S. aureus screening. A landmark randomized trial demonstrated that identifying S. aureus nasal carriers preoperatively and treating them with intranasal mupirocin and chlorhexidine body washing reduced the rate of S. aureus surgical-site infection by more than half compared with placebo, establishing targeted decolonization as an evidence-based component of perioperative infection prevention specifically for this organism [22]. The rectal ESBL E. coli and rectoanal MDRO colonization studies reviewed above suggest that an analogous logic could plausibly extend to Gram-negative organisms in tertiary settings with high background ESBL or carbapenem-resistance prevalence, but neither study evaluated a decolonization or prophylaxis-adjustment intervention directly, and the authors of both studies called instead for preoperative screening protocols and strengthened infection-control measures rather than universal decolonization, reflecting the comparative immaturity of Gram-negative decolonization strategies relative to the Staphylococcus-specific evidence base [8,10].

Discussion

Three findings recur with sufficient consistency across the tertiary-hospital literature reviewed here to support general conclusions. First, the causative organism spectrum of postoperative SSI has become substantially more Gram-negative and substantially more resistant across a wide range of geographic and economic settings, from Egypt and Tanzania to Pakistan, India, Malaysia, and Zambia, indicating that this is not a phenomenon confined to any single health system or resource level but a broadly generalizable shift in the epidemiology of surgical infection [2,4,1,3,14,10]. Second, the risk factors that predict resistant rather than merely any postoperative infection - prior antibiotic exposure, pre-existing MDRO colonization, prolonged intensive care or hospital stay, and major comorbidity such as diabetes - are largely identifiable before or shortly after admission, meaning that resistance risk is in principle predictable at the point of surgical decision-making rather than only discoverable retrospectively once culture results return [7,8,9]. Third, the dominant evidence-based response to date - narrow-spectrum, time-limited prophylaxis per the ASHP/IDSA/SHEA/SIS and CDC guidelines, reinforced by stewardship programs targeting guideline compliance - remains appropriate in aggregate but requires local calibration against institutional resistance surveillance data to remain clinically adequate in settings where ESBL and carbapenem resistance among SSI isolates has become common rather than exceptional [16,17,20].

These findings carry direct implications for tertiary-hospital practice. Institutions with documented high rates of ESBL-producing or carbapenem-resistant Gram-negative SSI isolates should consider whether standard cefazolin-based prophylaxis remains adequate for high-risk procedures (prolonged abdominal or hepatobiliary surgery, patients with recent antibiotic exposure or ICU stay) or whether a locally derived, antibiogram-informed prophylaxis protocol - potentially incorporating an aminoglycoside or a different beta-lactam for a defined high-risk subgroup - is warranted, while preserving narrow-spectrum prophylaxis for lower-risk procedures to avoid indiscriminately escalating resistance pressure hospital-wide. Antimicrobial stewardship programs should extend beyond auditing guideline compliance on antibiotic choice, dose, and duration to include active surveillance of the resistance profile of SSI isolates specifically, since the evidence reviewed here indicates that this profile can shift meaningfully within a single institution over a period of only a few years [14]. Preoperative MDRO colonization screening, well established for S. aureus, merits further prospective evaluation for Gram-negative organisms in tertiary settings where rectal ESBL or carbapenem-resistant Enterobacteriaceae carriage has been documented at rates sufficient to plausibly justify targeted intervention [22,10].

Perioperative prophylaxis and antimicrobial stewardship interventions relevant to antimicrobial-resistant surgical site infection, with reported effect and documented limitation.

Intervention	Mechanism	Reported effect	Documented limitation	Key reference
Guideline-based narrow-spectrum prophylaxis	Single-dose or <24h cefazolin-based regimen timed to incision	Established baseline SSI reduction across surgical specialties	Trial evidence base predates current high-AMR tertiary settings	Bratzler et al. 2013
Shorter vs. prolonged prophylaxis	Limiting antibiotic exposure duration after incision closure	No significant additional SSI reduction with prolonged regimens (RR 1.07)	Wide confidence intervals; sparse infection events in trials	Patni et al. 2026
Audit and feedback stewardship	Educational workshops plus prescribing audit and feedback	Improved compliance with antibiotic choice (p=0.001) and duration (p<0.001); reduced consumption	No improvement in administration timing compliance	Sefah et al. 2025
Preoperative S. aureus nasal screeningand decolonization	Mupirocin plus chlorhexidine in identified nasal carriers	More than halved S. aureus surgical-site infection rate	Evidence base not yet replicated for Gram-negative colonization	Bode et al. 2010
Multidisciplinary surgical stewardship teams	Integrating surgeons, pharmacists, microbiologists, and diagnostic biomarkers	Proposed to reduce unnecessary prolonged antibiotic use	Implementation remains limited relative to medical/ICU stewardship	Kourbeti et al. 2024

This review has several limitations inherent to its narrative rather than systematic design. The tertiary-hospital surveillance

studies synthesized here differ substantially in surgical case mix, culture and susceptibility-testing methodology, and resistance-definition thresholds, so the reported percentages should be read as illustrative of a directionally consistent pattern rather than pooled as though drawn from a single standardized measurement instrument. The literature search, while targeted and individually verified for each included source, was not exhaustive and may under-represent non-English-language surveillance literature from regions with a substantial AMR burden. Finally, because AMR epidemiology and surgical stewardship practice are evolving rapidly, some conclusions drawn from earlier studies may understate resistance patterns and stewardship practices that have since matured or, conversely, worsened.

Conclusion

Postoperative surgical site infection in tertiary care hospitals is increasingly caused by organisms - S. aureus/MRSA, E. coli, K. pneumoniae, and P. aeruginosa foremost among them - that no longer respond reliably to the antibiotic classes on which standard perioperative prophylaxis protocols were built, and this resistance burden is concentrated among patients with identifiable risk factors including prior antibiotic exposure, pre-existing MDRO colonization, prolonged hospital or intensive-care stay, and major comorbidity. Addressing this pattern does not require abandoning the evidence-based foundation of narrow-spectrum, time-limited perioperative prophylaxis established by international guidelines, but it does require that tertiary hospitals calibrate that foundation against their own, regularly updated resistance surveillance data, extend antimicrobial stewardship attention specifically to the surgical antibiotic prophylaxis and treatment pathway, and evaluate whether targeted preoperative screening - well validated for S. aureus and plausible but less thoroughly evaluated for resistant Gram-negative organisms - has a role in institutions where colonization with multidrug-resistant organisms has become common among surgical patients. Realizing this locally calibrated approach at scale, rather than relying solely on generalized international guidance, remains the central unmet task for antimicrobial stewardship in surgical care.

References

1. Ahmed R, Irfan S, Naeem M, Roshan R, Virani N, Mahmood F, Zafar H (2026) Incidence, microbiological spectrum, and antimicrobial resistance patterns of surgical site infections at a tertiary care hospital in Pakistan: a retrospective observational study. BMC Infectious Diseases, 26(1):1146, DOI:10.1186/s12879-026-13312-8.

2. Raouf M, Ghazal T, Kassem M, Agamya A, Amer A (2020) Surveillance of surgical-site infections and antimicrobial resistance patterns in a tertiary hospital in Alexandria, Egypt. The Journal of Infection in Developing Countries, 14(3):277-283, DOI:10.3855/jidc.12124.

3. Singh A, Sharma M, Kumar A (2025) Antimicrobial resistance in bacterial pathogens from postoperative surgical site infections in a tertiary care centre in India. BMC Microbiology, 25(1):721, DOI:10.1186/s12866-025-04480-9.

4. Manyahi J, Matee MI, Majigo M, Moyo S, Mshana SE, Lyamuya EF (2014) Predominance of multi-drug resistant bacterial pathogens causing surgical site infections in Muhimbili national hospital, Tanzania. BMC Research Notes, 7:500, DOI:10.1186/1756-0500-7-500.

5. Erinmez M, Birgin H, Yilmaz L, Zer Y (2025) Microbiological Findings and Risk Profiles in Hepatobiliary and Pancreatic Surgery Associated Surgical Site Infections: A Retrospective Cohort Study. Pathogens, 14(12):1215, DOI:10.3390/pathogens14121215.

6. El Menofy N, Tawfick MM, Badawy MSEM (2025) Molecular study of carbapenem-resistant Pseudomonas aeruginosa causing wound infection in an Egyptian tertiary hospital. The Journal of Infection in Developing Countries, 19(7):997-1006, DOI:10.3855/jidc.19953.

7. Ambrosie L, Dan M, Ilie OD, Condrea TD, Purice M, Blaj M, Ionescu L, Timofte DV (2026) Risk Factors and Antibiotic Utilization Patterns in Multidrug-Resistant Surgical Infections: A Retrospective Study From a Romanian Tertiary-Care Center. International Journal of Microbiology, 2026:6286424, DOI:10.1155/ijm/6286424.

8. Li J, Gao L, Wang C, Tu J, Chen W, Wu X, Wu J (2023) Colonization of multidrug-resistant Gram-negative bacteria increases risk of surgical site infection after hemorrhoidectomy: a cross-sectional study of two centers in southern China. International Journal of Colorectal Disease, 38(1):243, DOI:10.1007/s00384-023-04535-1.

9. Friedman ND, Sexton DJ, Connelly SM, Kaye KS (2007) Risk factors for surgical site infection complicating laminectomy. Infection Control & Hospital Epidemiology, 28(9):1060-1065, DOI:10.1086/519864.

10. Siame A, Yamba K, Samutela M, Mukubesa A, Mulundu G (2024) Carriage and antimicrobial susceptibility patterns of rectal ESBL E. coli in surgical patients at the University Teaching Hospitals in Lusaka, Zambia. JAC-Antimicrobial Resistance, 6(5):dlae159, DOI:10.1093/jacamr/dlae159.

11. Tacconelli E, Carrara E, Savoldi A, Harbarth S, Mendelson M, Monnet DL, et al (2018) Discovery, research, and development of new antibiotics: the WHO priority list of antibiotic-resistant bacteria and tuberculosis. The Lancet Infectious Diseases, 18(3):318-327, DOI:10.1016/S1473-3099(17)30753-3.

12. Culver DH, Horan TC, Gaynes RP, Martone WJ, Jarvis WR, Emori TG, et al (1991) Surgical wound infection rates by wound class, operative procedure, and patient risk index. National Nosocomial Infections Surveillance System. American Journal of Medicine, 91(3B):152S-157S, DOI:10.1016/0002-9343(91)90361-Z.

13. Mawalla B, Mshana SE, Chalya PL, Imirzalioglu C, Mahalu W (2011) Predictors of surgical site infections among patients undergoing major surgery at Bugando Medical Centre in Northwestern Tanzania. BMC Surgery, 11:21, DOI:10.1186/1471-2482-11-21.

14. Muhamad AN, Teh CSJ, Draman MR, Adnan YK, Amir Abbas A, Khong TL, Narayanan V, Tang SN, Karunakaran R, Ab Manan N, Kukreja A, Mohamad Razali SZ, Cham CY, Hontz RD, Gregory MJ, Selariu A, Nguyen HC, Letizia AG, Sri La Sri Ponnampalavanar S (2025) High incidence of multidrug-resistant organisms and modifiable risk factors associated with surgical site infections: a cohort study in a tertiary medical center in Kuala Lumpur, Malaysia from 2020 to 2023. Antimicrobial Resistance & Infection Control, 14:22,

DOI:10.1186/s13756-025-01537-2.

15. Ali A, Gebretsadik D, Desta K (2023) Incidence of surgical site infection, bacterial isolate, and their antimicrobial susceptibility pattern among patients who underwent surgery at Dessie Comprehensive Specialized Hospital, Northeast Ethiopia. SAGE Open Medicine, 11:20503121231172345, DOI:10.1177/20503121231172345.

16. Bratzler DW, Dellinger EP, Olsen KM, Perl TM, Auwaerter PG, Bolon MK, Fish DN, Napolitano LM, Sawyer RG, Slain D, Steinberg JP, Weinstein RA (2013) Clinical practice guidelines for antimicrobial prophylaxis in surgery. American Journal of Health-System Pharmacy, 70(3):195-283, DOI:10.2146/ajhp120568.

17. Berrios-Torres SI, Umscheid CA, Bratzler DW, Leas B, Stone EC, Kelz RR, Reinke CE, Morgan S, Solomkin JS, Mazuski JE, Dellinger EP, Itani KMF, Berbari EF, Segreti J, Parvizi J, Blanchard J, Allen G, Kluytmans JAJW, Donlan R, Schecter WP (2017) Centers for Disease Control and Prevention guideline for the prevention of surgical site infection, 2017. JAMA Surgery, 152(8):784-791, DOI:10.1001/jamasurg.2017.0904.

18. Patni MM, Alabid I, Abedi M, El-Tanani M, Rangraze I, Rabbani SA, Salama RAA, Elayyan KW, Menon A (2026) Shorter versus prolonged systemic perioperative antibiotic prophylaxis in clean orthopedic surgery: A systematic review and meta-analysis. Antibiotics, 15(8):759, DOI:10.3390/antibiotics15080759.

19. Martinez-Sobalvarro JV, Pereira Junior AA, Pereira LB, Baldoni AO, Ceron CS, Reis TM (2021) Antimicrobial stewardship for surgical antibiotic prophylaxis and surgical site infections: a systematic review. International Journal of Clinical Pharmacy, 43(2):301-319, DOI:10.1007/s11096-021-01358-4.

20. Sefah IA, Chetty S, Yamoah P, Bangalee V (2025) The impact of antimicrobial stewardship interventions on surgical antibiotic prophylaxis guidelines compliance in a teaching hospital in Ghana. PLOS ONE, 20(8):e0329541, DOI:10.1371/journal.pone.0329541.

21. Kourbeti I, Kamiliou A, Samarkos M (2024) Antibiotic stewardship in surgical departments. Antibiotics, 13(4):329, DOI:10.3390/antibiotics13040329.

22. Bode LGM, Kluytmans JAJW, Wertheim HFL, Bogaers D, Vandenbroucke-Grauls CMJE, Roosendaal R, Troelstra A, Box ATA, Voss A, van der Tweel I, van Belkum A, Verbrugh HA, Vos MC (2010) Preventing Surgical-Site Infections in Nasal Carriers of Staphylococcus aureus. New England Journal of Medicine, 362(1):9-17, DOI:10.1056/NEJMoa0808939.