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Review article

ANTIMICROBIAL STEWARDSHIP ACROSS THE SURGICAL PATHWAY

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Abstract: Antimicrobial stewardship programs (ASPs) help ensure antibiotics are used effectively to treat infections, reduce side effects, and slow the spread of antibiotic resistance. Improving collaboration among healthcare professionals is the most important way to strengthen ASPs in hospitals.

So far, most ASPs have focused on medical specialities and applied the same approach to all hospital settings. In surgery, it is essential to understand the local cultural and contextual factors that shape prescribing habits so targeted strategies can be developed. Antibiotic stewardship in surgery must be integrated with strict infection prevention and source control, as all three work together to improve patient care.

Effective ASPs usually combine persuasive strategies, which educate and influence prescribers, with restrictive ones, which limit certain practices. While clinical guidelines turn evidence into practice and improve the quality of care, they do not always fit local realities. Adapting them into locally relevant tools, such as protocols, bundles, checklists, and posters, can boost acceptance and adherence. Actively involving prescribers in developing these tools increases the likelihood of meaningful change. Clearly defining responsibilities for specific actions within these protocols helps ensure they are followed.

Keywords: antimicrobial stewardship, antibiotic resistance, antibiotic prescribing, infection prevention, source control, multimodal approach.

INTRODUCTION

Antibiotics have played a crucial role in saving countless lives and making surgical procedures much safer. Safe surgical care relies heavily on access to effective antibiotics to prevent and treat infections. Yet, despite their vital role, antibiotics are frequently used inappropriately, creating challenges in surgical practice. Improving antibiotic prescribing in surgery is essential to enhance patient outcomes, reduce the risk of side effects, and curb the spread of antimicrobial resistance (AMR).

The multimodal approach to infections

Strategies to optimise antibiotic use in surgery involve a multimodal approach, primarily based on infection prevention and control measures, which are essential to reduce the use of broad-spectrum antibiotics in hospitals. Infection prevention and control (IPC) programmes are an integral part of modern healthcare systems, using evidence-based approaches to prevent healthcare-associated infections (HAIs). Patients with HAIs often require additional diagnostic and therapeutic interventions, have prolonged hospital stays, incur extra costs, and face higher morbidity and mortality risks. In particular, managing patients with HAIs often requires broad-spectrum antibiotic regimens due to the high risk of multidrug-resistant bacteria (1).

Surgical patients are especially susceptible to hospital-acquired infections and more vulnerable to their consequences. Surgical site infections (SSIs) are the leading type of hospital-acquired infection in surgical patients. Recently, many sets of guidelines based on evidence have been developed for preventing SSIs throughout all stages of surgery—before, during, and after the procedure (2–8). Despite this, compliance with these recommended best practices remains low (9). Furthermore, other healthcare-associated infections—such as catheter-associated urinary tract infections, central-line–associated bloodstream infections, hospital-acquired pneumonia, ventilator-associated pneumonia, and Clostridioides difficile infections—represent major safety concerns in postoperative care.

Since many hospital-acquired infections are partly preventable, implementing prevention strategies is

essential for patient safety in hospitals (10). Nevertheless, healthcare workers often fail to adhere to evidence-based preventive measures (11). A prime example is hand hygiene, considered both a patient safety indicator and the cornerstone of IPC in all healthcare settings. Although universally recognised as effective and cost-efficient, hand hygiene compliance remains unacceptably low.

In surgery, antibiotics play a major role, prescribed either as surgical prophylaxis or therapy. Surgical antibiotic prophylaxis (SAP) significantly contributes to overall antibiotic use in hospitals, accounting for around 15% of all prescriptions (12). SAP is recommended for clean-contaminated procedures with an increased SSI risk or clean procedures where even unlikely SSIs could have severe consequences—such as those involving prosthetic implants. However, antibiotics alone cannot prevent SSIs, and all prevention measures must be implemented alongside them (13).

In general, SAP should be administered 30–60 minutes before incision for the most commonly used antibiotics (including cefazolin). Intraoperative re-dosing is indicated for surgeries exceeding twice the antibiotic's half-life or involving significant blood loss. In principle, SAP should always be discontinued after surgery. Unfortunately, inappropriate SAP prescribing remains consistently high in surgical settings (14).

Antibiotic therapy is a cornerstone of daily surgical practice, with surgeons often on the frontline of managing patients with complicated infections. Because microbiology results take time, antibiotic therapy is initially empirical, prescribed based on symptoms and likely pathogens. Targeted therapy begins once microbial identification and susceptibility results are available, ensuring effective antibiotic use. Optimal targeted therapy requires early pathogen identification, but even with advances in rapid diagnostics, microbiology results can take up to 72 hours.

Surgeons should acknowledge that proper antibiotic prescribing is a core part of surgical practice and recognise that antibiotic stewardship is closely linked to surgical work, playing a key role in both patient care and treatment effectiveness (15).

A recent call to action highlighted the importance of optimal antibiotic use in hospitals, proposing ten "golden rules" to guide clinicians—emphasising the need to prescribe the right antibiotic for the right patient, at the right dose, via the right route, for the right duration—and stressing a collaborative approach to uphold these principles (2).

In surgical infections, source control is both feasible and highly impactful for improving patient outcomes. Appropriate source control can enhance recovery and reduce antibiotic use, allowing for shorter treatment courses. Source control encompasses measures to eliminate the infection source and stop ongoing contamination, requiring a thorough understanding of pathophysiology, host response, surgical and nonsurgical options, and a balanced mix of therapeutic aggressiveness and cautious decision-making.

The reduction of antibiotic treatment duration for patients with complicated intra-abdominal infections is now well established, especially when optimal source control is achieved. In such cases, short antibiotic courses following adequate source control are a reasonable option (16).

Antimicrobial stewardship programs (ASP) in surgery

Antimicrobial stewardship programs (ASPs) are now considered a key initiative to optimise antibiotic use, improve patient outcomes, and curb AMR emergence. ASPs can optimise antibiotic therapy and reduce antibiotic-associated adverse events (17). Evidence shows they can significantly reduce multidrug-resistant bacterial infections and *C. difficile* colonisation in hospitals. Hospitals worldwide should leverage existing resources to organise effective interdisciplinary teams (18, 19).

Fifteen years after the first joint guidelines for institutional ASP development (20), practices remain poorly defined and vary according to local models and available resources. Traditionally, hospital ASPs have focused mainly on medical specialities, often applying a one-size-fits-all approach across settings. However, antibiotic decision-making for surgical patients should be developed separately and requires a necessarily collaborative approach involving a multidisciplinary network.

Key ASP strategies should combine persuasive and restrictive approaches. Persuasive strategies aim to improve prescriber knowledge, shift attitudes, and influence prescribing behaviour through persuasion—generally better accepted and more educational than restrictive strategies, which, while potentially more effective short term, do not actively engage surgeons in changing behaviour.

Preauthorisation means that prescribers must obtain permission before they can prescribe specific antibiotics. This can reduce unnecessary or inappropriate antibiotic use, particularly for preserving newer-generation drugs for multidrug-resistant infections. In some contexts, preauthorisation also applies to drugs such as fluoroquinolones, now recommended only in specific cases due to side effects and resistance potential. Evidence supports restrictive interventions when urgent, but shows persuasive and restrictive strategies to be equally effective long term. However, preauthorisation can be time-consuming, and some hospitals lack staff to manage it.

Restrictive measures overlook the appropriateness of unrestricted antibiotics, which make up the majority of hospital prescriptions, potentially leading to increased use of these drugs—a phenomenon known as the "squeezing the balloon" effect. Additionally, restricting antibiotics may impact surgeon autonomy, creating barriers to collaboration and reducing essential communication for effective stewardship.

Improving hospital ASPs should always involve interprofessional collaboration. ASPs should include infectious disease specialists and clinical pharmacists trained in infectious diseases, closely allied with clinical microbiologists. Infection prevention specialists and hospital epidemiologists should coordinate infection monitoring and prevention, with strong support from hospital administrators. Importantly, surgeons' involvement in ASPs is essential.

Studies have shown low surgeon awareness regarding antibiotic prescribing, with antibiotics often considered a low-priority task (21). Surgeons tend to prioritise surgical outcomes, with fear of poor results outweighing concerns over inappropriate prescribing. This can lead to extended prophylaxis, delayed discontinuation post-surgery, or prolonged therapy after source control. Limited ward time due to operating theatre demands often shifts responsibility to junior staff without decision-making authority. Thus, expecting surgeons to fully integrate stewardship into daily practice can be challenging (22).

To improve prescribing initiatives, structural and cultural determinants of antibiotic use in surgery must be addressed. Factors such as fear of clinical failure, time pressure, and organisational constraints complicate decision-making. Due to cognitive dissonance—knowing an action is needed but failing to take it—changing prescribing behaviour is difficult.

Raising surgeon awareness about appropriate antibiotic use is therefore essential. Individually, each physician should have the knowledge, skills, and abilities to implement effective prescribing practices. Antibiotic prescribing education should be part of all medical training, including surgical curricula. While increasing knowledge can influence perceptions and motivate change, knowledge alone is rarely enough for lasting improvement, as habits and established practices are hard to alter.

Training alone has a limited impact without accompanying interventions. Successful strategies have included adapting guidelines into local protocols, defining specific responsibilities, and actively involving surgeons. Such engagement can lead to meaningful cultural change towards shared protocol adherence. Conversely, restrictive, punitive mandates should be avoided, as they tend to foster only superficial compliance.

Hospitals with strong safety cultures can promote education, communication, and collaboration. In this environment, surgeons are more likely to engage with infectious disease specialists, hospital pharmacists, and microbiologists.

A prospective audit and feedback strategy is a common stewardship intervention, aiming to maintain prescriber autonomy while improving antibiotic use (23). This strategy is particularly suitable for surgery, is better accepted than restrictive approaches, and provides educational opportunities through feedback. In surgery, it has been associated with shorter hospital stays and treatment durations (24, 25).

Identifying a local opinion leader or "champion" is also important, as such individuals can integrate best practices, motivate peers, and collaborate with IPC and ASP teams. This "champion" model has already proven effective in surgical safety initiatives such as checklists.

Future directions

To further strengthen antimicrobial stewardship in surgery, innovative strategies should be explored. Digital prescribing tools, such as electronic prescribing systems with built-in clinical decision support, can help guide antibiotic choice, timing, and duration, while also flagging inappropriate practices in real time. Similarly, rapid diagnostic technologies offer opportunities for earlier pathogen identification and antimicrobial susceptibility testing, reducing unnecessary empirical therapy and allowing faster transitions to targeted treatment.

Another promising area involves the application of structured behavioural science methods to address cultural and psychological drivers of antibiotic prescribing. Approaches such as nudges, feedback loops, and behavioral incentives can complement traditional educational and guideline-based interventions, making stewardship efforts more sustainable.

At the same time, stewardship strategies must be realistic and adaptable to low-resource settings, where access to diagnostics, trained personnel, and digital infrastructure may be limited. In such environments, simplified protocols, context-specific guidelines, and innovative capacity-building models are essential. Implementation science approaches should be used to anticipate barriers and design scalable solutions that maintain effectiveness while fitting local realities (26).

CONCLUSION

ASPs can optimize antibiotic treatment and reduce adverse events. To date, hospital ASPs have largely focused on medical specialities with uniform approaches, but understanding the contextual and cul-

tural factors behind surgical prescribing is essential for targeted interventions. Antimicrobial stewardship cannot be separated from infection prevention/control and appropriate source control, as all three are interconnected throughout the surgical pathway.

The best way to improve stewardship in general and emergency surgical units worldwide is to foster cross-speciality collaboration. Identifying a local "champion" can help integrate best practices and drive behavioural change. Surgeons with expertise in surgical infections, when involved in ASPs, can review prescriptions, provide feedback, promote best practices, and serve as liaisons between IPC and stewardship teams.

Key ASP strategies should combine persuasive and selective restrictive measures. While guidelines can translate evidence-based practices into clinical reality, they must be adapted locally to improve acceptance and adherence. Local protocols, bundles, checklists, and posters can help, especially when prescribers are directly involved in their development.

A prospective audit and feedback strategy, by preserving prescriber autonomy while enhancing prescribing quality, is easily applicable to surgery. Ultimately, collaboration is essential for maximising patient outcomes and improving healthcare delivery. Multidisciplinary teams bring together specialised skills to deliver coordinated care through agreed-upon plans.

Abbreviations

ASP - Antimicrobial Stewardship Program
AMR - Antimicrobial Resistance
IPC - Infection Prevention and Control
HAI(s) - Healthcare-Associated Infection(s)
SSI(s) - Surgical Site Infection(s)
SAP - Surgical Antibiotic Prophylaxis
C. difficile - *Clostridioides difficile*
OR - Operating Room

Conflict of Interest Statement

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Note: Artificial intelligence was not utilized as a tool in this study.

Sažetak

NADZOR I KONTROLA KORIŠĆENJA ANTIMIKROBNIH LEKOVA U HIRURGIJI

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Programi za racionalnu upotrebu antibiotika (eng. Antimicrobial Stewardship Programs – ASP) pomažu u osiguravanju efikasne primene antibiotika za lečenje infekcija, smanjenju neželjenih efekata i usporavanju širenja rezistencije na antibiotike. Poboljšanje saradnje među zdravstvenim profesionalcima predstavlja ključni način za jačanje ovih programa u bolnicama.

Do sada se većina ovih programa fokusirala na medicinske specijalnosti i primenjivala isti pristup u svim bolničkim sredinama. U hirurgiji je od suštinskog značaja razumevanje lokalnih kulturnih i kontekstualnih faktora koji oblikuju navike propisivanja antibiotika, kako bi se razvile ciljne strategije. Racionalna upotreba antibiotika u hirurgiji treba da bude integrisana sa strogom prevencijom infekcija i kontrolom izvora infekcije, jer sve tri komponente deluju zajedno na poboljšanje nege pacijenata.

Efikasni ASP obično kombinuju uverljive strategije, koje edukuju i utiču na lekare koji propisuju lekove, sa restriktivnim strategijama, koje ograničavaju određene prakse. Iako kliničke smernice prevode dokaze u praksu i poboljšavaju kvalitet nege, one se ne uklapaju uvek u lokalne realnosti. Njihova adaptacija u lokalno relevantne alate, poput protokola, „bundlova", kontrolnih lista i postera, može povećati prihvatanje i pridržavanje. Aktivno uključivanje propisivača lekova u razvoj ovih alata povećava verovatnoću značajnih promena u praksi. Jasno definisanje odgovornosti za specifične aktivnosti unutar protokola pomaže da se osigura njihovo sprovođenje.

***Ključne reči**:* racionalna upotreba antibiotika, rezistencija na antibiotike, propisivanje antibiotika, prevencija infekcija, kontrola izvora infekcije, multimodalni pristup.

REFERENCES

1. Sartelli M, Labricciosa FM, Barbadoro P, Pagani L, Ansaloni L, Brink AJ, et al. The Global Alliance for Infections in Surgery: defining a model for antimicrobial stewardship—results from an international cross-sectional survey. World J Emerg Surg. 2017; 12:34. doi: 10.1186/s13017-017-0145-2.

2. Worldwide Antimicrobial Resistance National/International Network Group (WARNING) Collaborators. Ten golden rules for optimal antibiotic use in hospital settings: the WARNING call to action. World J Emerg Surg. 2023; 18(1): 50. doi: 10.1186/s13017-023-00518-3.

3. Allegranzi B, Zayed B, Bischoff P, Kubilay NZ, de Jonge S, de Vries F, et al. New WHO recommendations on intraoperative and postoperative measures for surgical site infection prevention: an evidence-based global perspective. Lancet Infect Dis. 2016; 16(12): e288-e303. doi: 10.1016/S1473-3099(16)30402-9.

4. Allegranzi B, Bischoff P, de Jonge S, Kubilay NZ, Zayed B, Gomes SM, et al. New WHO recommendations on preoperative measures for surgical site infection prevention: an evidence-based global perspective. Lancet Infect Dis. 2016; 16(12): e276-87. doi: 10.1016/S1473-3099(16)30398-X.

5. Berríos-Torres SI, Umscheid CA, Bratzler DW, Leas B, Stone EC, Kelz RR, et al. Centers for disease control and prevention guideline for the prevention of surgical site infection, 2017. JAMA Surg. 2017; 152(8): 784-91. doi: 10.1001/jamasurg.2017.0904.

6. Ban KA, Minei JP, Laronga C, Harbrecht BG, Jensen EH, Fry DE, et al. American College of Surgeons and Surgical Infection Society: surgical site infection guidelines, 2016 Update. J Am Coll Surg. 2017 Jan; 224(1): 59-74. doi: 10.1016/j.jamcollsurg.2016.10.029.

7. National Institute for Health and Care Excellence. Surgical site infections: prevention and treatment. NICE guideline [NG125]. Available at: https://www.nice.org.uk/guidance/ng125. Last accessed: 18 November 2024.

8. Anderson DJ, Podgorny K, Berríos-Torres SI, Bratzler DW, Dellinger EP, Greene L, et al. Strategies to prevent surgical site infections in acute care hospitals: 2014 update. Infect Control Hosp Epidemiol. 2014; 35(6): 605-27. doi: 10.1086/676022.

9. Sartelli M, Bartoli S, Borghi F, Busani S, Carsetti A, Catena F, et al. Implementation strategies for preventing healthcare-associated infections across the surgical pathway: an Italian multisociety document. Antibiotics (Basel). 2023; 12(3): 521. doi: 10.3390/antibiotics12030521.

10. Schreiber PW, Sax H, Wolfensberger A, Clack L, Kuster SP; Swissnoso. The preventable proportion of healthcare-associated infections 2005-2016: Systematic review and meta-analysis. Infect Control HospEpidemiol. 2018; 39(11): 1277-95. doi: 10.1017/ice.2018.183.

11. Sartelli M, Labricciosa FM, Coccolini F, Coimbra R, Abu-Zidan FM, Ansaloni L, et al. It is time to define an organizational model for the prevention and management of infections along the surgical pathway: a worldwide cross-sectional survey. World J Emerg Surg. 2022; 17(1): 17. doi: 10.1186/s13017-022-00420-4.

12. Bratzler DW, Dellinger EP, Olsen KM, Perl TM, Auwaerter PG, Bolon MK, et al. Clinical practice guidelines for antimicrobial prophylaxis in surgery. Am J Health Syst Pharm. 2013; 70(3): 195-283. doi: 10.2146/ajhp120568.

13. Sartelli M, Coccolini F, Labricciosa FM, Al Omari AH, Bains L, Baraket O, et al. Surgical antibiotic prophylaxis: a proposal for a global evidence-based bundle. Antibiotics (Basel). 2024; 13(1): 100. doi: 10.3390/antibiotics13010100.

14. Ierano C, Thursky K, Marshall C, Koning S, James R, Johnson S, et al. Appropriateness of surgical antimicrobial prophylaxis practices in Australia. JAMA Netw Open. 2019; 2(11): e1915003. doi: 10.1001/jamanetworkopen.2019.15003.

15. Sartelli M, Duane TM, Catena F, Tessier JM, Coccolini F, Kao LS, et al. Antimicrobial stewardship: a call to action for surgeons. Surg Infect (Larchmt). 2016; 17(6): 625-31. doi: 10.1089/sur.2016.187.

16. Sawyer RG, Claridge JA, Nathens AB, Rotstein OD, Duane TM, Evans HL, et al. Trial of short-course antimicrobial therapy for intraabdominal infection. N Engl J Med. 2015; 372(21): 1996-2005. doi: 10.1056/NEJMoa1411162.

17. Global Alliance for Infections in Surgery collaborators group. A global declaration on appropriate use of antimicrobial agents across the surgical pathway. Surg Infect (Larchmt). 2017; 18(8): 846-53. doi: 10.1089/sur.2017.219.

18. Davey P, Brown E, Charani E, Fenelon L, Gould IM, Holmes A, et al. Interventions to improve antibiotic prescribing practices for hospital inpatients. Cochrane Database Syst Rev. 2013; (4): CD003543. doi: 10.1002/14651858.CD003543.pub3.

19. Goff DA, Kullar R, Goldstein EJC, Gilchrist M, Nathwani D, Cheng AC, et al. A global call from five countries to collaborate in antibiotic stewardship: united we succeed, divided we might fail. Lancet Infect Dis. 2017; 17(2): e56-e63. doi: 10.1016/S1473-3099(16)30386-3.

20. Dellit TH, Owens RC, McGowan JE Jr, Gerding DN, Weinstein RA, Burke JP et al. Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. Clin Infect Dis. 2007; 44(2): 159-77. doi: 10.1086/510393.

21. Charani E, Tarrant C, Moorthy K, Sevdalis N, Brennan L, Holmes AH. Understanding antibiotic decision making in surgery-a qualitative analysis. Clin Microbiol Infect. 2017; 23(10): 752-60. doi: 10.1016/j.cmi.2017.03.013.

22. Charani E, Ahmad R, Rawson TM, Castro-Sanchèz E, Tarrant C, Holmes AH. The differences in antibiotic decision-making between acute surgical and acute medical teams: an ethnographic study of culture and team dynamics. Clin Infect Dis. 2019; 69(1): 12-20. doi: 10.1093/cid/ciy844.

23. Brink AJ, Messina AP, Feldman C, Richards GA, van den Bergh D; Netcare Antimicrobial Stewardship Study Alliance. From guidelines to practice: a pharmacist-driven prospective audit and feedback improvement model for peri-operative antibiotic prophylaxis in 34 South African hospitals. J Antimicrob Chemother. 2017; 72(4): 1227-34. doi: 10.1093/jac/dkw523.

24. Elligsen M, Walker SA, Simor A, Daneman N. Prospective audit and feedback of antimicrobial stewardship in critical care: program implementation, experience, and challenges. Can J Hosp Pharm. 2012; 65(1): 31-6. doi: 10.4212/cjhp.v65i1.1101.

25. Chan AJ, Tsang ME, Langford BJ, Nisenbaum R, Wan M, Downing MA. Evaluating a pilot, structured, face-to-face,

antimicrobial stewardship, prospective audit-and-feedback program in emergency general surgery service in a community hospital. Antimicrob Steward HealthcEpidemiol. 2023; 3(1): e96. doi: 10.1017/ash.2023.168.

26. Sartelli M. Leveraging the synergy between antimicrobial stewardship and infection prevention and control in fighting antimicrobial resistance. Sanamed. 2021; 16(3): 231-3. doi: 10.24125/sanamed.v16i3.524.

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