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# Medication-Related Problems Across The Continuum Of Care In Hospital-Acquired Infections: A Disease-Based Clinical Review

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**Abstract**

Hospital-Acquired Infections (HAIs) are a significant healthcare issue worldwide that has caused significant morbidity and mortality in patients, extended hospitalization, and increased healthcare expenditures. Antimicrobial resistance, biofilm-related pathogens, invasive medical equipment, and a high incidence of medication-related issues (MRP) throughout the continuum of care are increasing the complexity of HAIs management. These issues are usually caused by improper antimicrobial use, dose, drug-drug interactions, adverse drug reactions, and medication reconciliation issues in case of care transitions. Biofilm forming organisms like Staphylococcus aureus, Klebsiella pneumoniae, Pseudomonas aeruginosa, and Acinetobacter baumannii also play a bigger role in compromising the treatment efficacy since it decreases the antimicrobial penetration and enhances tolerance and resistance. The present review presents a disease-focused approach to clinical pharmacy on MRPs that take place pre-admission (before admission), in hospital (during hospitalization), transitions of care (acute care), and post-discharge in patients with HAIs. It emphasizes the importance of clinical pharmacists in the identification, prevention, and resolution of the MRPs using antimicrobial stewardship programs, therapeutic drug monitoring, medication reconciliation, deprescribing strategies, and educating patients. Interventions by pharmacists have continued to show decreases in adverse drug events, prescribing of incorrect medications, antimicrobial misuse, readmission, and cost of healthcare and have also led to better clinical outcomes and patient safety. The emerging challenges are also included in the review, such as environmental-driven resistance factors, like the microplastics and the hospital wastewater, and the perspectives in the future, which includes the implementation of precision medicine, fast-diagnosis, and artificial intelligence-based decision making. The main idea to improve the antimicrobial therapy, decrease MRPs and enhance the outcomes of patients with hospital-acquired infections is strengthening clinical pharmacy services across the continuum of care.

**Keywords** Hospital-acquired infections; Medication-related problems; Antimicrobial stewardship; Biofilms; Transitions of care; Drug–drug interactions.

## Introduction

The hospital-acquired infections are a challenge in current healthcare whose contribution to morbidity, mortality, and healthcare expenditures is high. These are also referred to as nosocomial infections, which are acquired by patients in the hospital and which they did not have or were not incubating when they were admitted (Bouhrour et al., 2024). They may take many clinical manifestations, such as pneumonia, urinary tract infections, and bloodstream infections, typically requiring complicated antimicrobial treatment (Hincu et al., 2024). Multidrug-resistant pathogens are also widespread, and they make treatment more complicated because they frequently result in longer hospitalization and worse patient outcomes (Khan et al., 2024). Most of them are device-related and are caused by the utilization of indwelling medical equipment that gives surfaces to microbial colonization and consequent biofilm formation that makes them difficult to diagnose and treat (VanEpps & Younger, 2016).

The growing problem of antimicrobial resistance complicates the burden of such infections, placing them at risk of poor clinical outcomes and medical costs (Dighriri et al., 2023; Nguyen et al., 2021). In turn, the management of medication-related issues at the continuum of care is vital to reducing the effect of hospital-acquired infections and enhancing patient safety and financial performance (Ioannou & Kofteridis, 2025). In particular, one of the largest subsets of HAIs includes device-related infections, including catheter-related bloodstream infection, catheter-associated urinary tract infection, and ventilator-associated pneumonia, whose occurrence rate increases due to the increased use of devices and changing patterns of antibiotic resistance (Dadi et al., 2021; Singhai et al., 2012; VanEpps and Younger, 2016).

These infections are often associated with the development of biofilms on medical devices that are complex communities of microorganisms surrounded by an extracellular polymeric substance that provides a significant level of protection against antimicrobial agents and host immune responses (Bouhrour et al., 2024; Francolini and Donelli, 2010). The protective matrix that is formed by the biofilms makes these biofilms incredibly resistant to standard antibiotic treatments and the host immune response, particularly those that initially start on the surface of the device or point of insertion through the hematogenous dissemination, localized colonization, or cross-contamination (Kosmeri et al., 2024). The economic cost of these infections is high, and HAIs are the leading contributors to the annual healthcare expenses of about 30 billion in the United States and related to about 50,000 mortalities each year (Cabal et al., 2019). This economic and human cost justifies the necessity of detailed measures that should be taken to prevent and control HAIs (Sartelli et al., 2023). Biofilm development on medical devices is the most problematic since these organized microbiological communities are very strong, increasing antimicrobial resistance and requiring complex methods of treatment, including the removal of devices (Khardori and Yassien, 1995; Li et al., 2023).

Multidrug resistance in biofilms of HAIs is widely dispersed across the world, with such frequent bacterial isolates as Staphylococcus aureus, Acinetobacter baumannii, Klebsiella pneumoniae, and Pseudomonas aeruginosa (Assefa & Amare, 2022). The presence of these pathogens, frequently with multidrug resistance, highlights the necessity of the implementation of highly advanced infection prevention and control techniques in addition to the development of new therapeutic methods to deal with biofilm-mediated infections (Sandu et al., 2025). The formation of biofilms is a major factor of HAIs maintenance and tolerance to antibiotic treatment and the immune system (Assefa and Amare, 2022; Bouhrour et al., 2024). This increases the resistance towards antimicrobial agents in biofilms which in many cases causes recurrent infections making the patient management more difficult and extending the hospital stay (Dadi et al., 2021).

## Background of Hospital-Acquired Infections (HAIs)

### Definition and Epidemiology of HAIs

According to the definitions of healthcare popularized by the World Health Organization, healthcare-associated infections are infections contracted within a healthcare environment during health care delivery, and were not present or incubating at the point of admission. The infections pose a serious worldwide issue, with millions of patients contracting these infections every year and these infections incurring high economic costs to the healthcare systems (Mishra et al., 2024). It has been estimated, on

a global scale, that about 1 out of 31 hospitalized patients contracts at least one HAI during hospitalization, which results in almost 2 million infections in the United States alone (Hassan et al., 2025). One of the leading factors that make such infections recalcitrant is the presence of biofilms, and an estimated 65% of nosocomial infections and 80% of chronic infections are due to biofilms (Assefa & Amare, 2022). The fact that these microbial communities can stick to biotic and abiotic surfaces, especially the medical equipment, contributes to the chronic infection and represents a protective niche against host defense and antimicrobial treatments (Bouhrour et al., 2024).

**Common Types of HAIs**

The importance of these biofilms is that they largely enhance bacterial resistance and make it difficult to treat and a major contributor to multidrug resistance in hospital-acquired infections in the world (Almatroudi, 2025; Maillard and Centeleghe, 2023). Popular pathogens commonly found in HAIs are Staphylococcus aureus/MRSA, Klebsiella pneumoniae, Pseudomonas aeruginosa, Enterococci (VRE), Escherichia coli, and Acinetobacter baumannii, most of which are capable of forming biofilms (Abreu et al., 2013; Alkhowaiter et al., 2024; Dadi et al., 2021). These biofilms have a complex architecture, which is an extracellular polymeric substance matrix that protects bacterial cells against the penetration of antibiotics or the immune system, allows persistent infections and makes it challenging to eradicate the bacteria (Abdelhamid and Yousef, 2023; Almatroudi, 2025; Maillard and Centeleghe, 2023).

This resistance may be 1000 times higher than of planktonic bacteria, and it makes a regular antimicrobial regimen ineffective (Almatroudi, 2025). Hospital-acquired infections have a significant effect globally, and it is estimated that millions of cases are recorded annually creating more morbidity, mortality, and healthcare spending (Chaudhury, 2018). The fact that the financial cost is alone in the billions of dollars per year in the United States is a repudiation of the urgent necessity to find effective measures on preventing and managing HAIs (Bakri et al., 2022). Such a worrying situation requires a detailed knowledge of the pathogenesis of HAIs, especially those related to the formation of biofilms, to direct the creation of specific interventions. This review will examine the complex dimensions of medication-related issues in the continuum of care and their role in causing HAIs and the possible pharmaceutical measures to alleviate their effects. In particular, this will involve the analysis of the role of different pathogens, including the presence of various pathogens, including, but not limited to, Escherichia coli and Klebsiella pneumoniae, in biofilm-related infections because they are increasingly becoming resistant to traditional antimicrobial agents (Ben-Amram et al., 2024; Bouhrour et al., 2024).

**Clinical and Economic Burden of HAIs**

HAIs, especially the use of biofilm-forming organisms, have a high rate of increasing hospital stays, healthcare expenditure, and patient mortality and morbidity (Dadi et al., 2021; Vergalito et al., 2019). HAIs impact 4.4 of 100 patient admissions across Kenya with higher rates in the medical and pediatric departments and a high rate of 9.3 percent in the area of surgical site infections (Odoyo et al., 2023). The financial impact of these infections is significant and millions of dollars of extra healthcare spending on long hospitalizations, diagnostic tests and antibiotic treatments are required every year to cope with them. This fiscal strain is also intensified by the emergence of antimicrobial resistance, especially in biofilm-related infections that usually necessitate more costly and vigorous treatment methods (Lu et al., 2019).

One such HAI per device has the potential to result in a financial cost of more than 10,000 euros per patient, indicating the massive economic impact of these infections (Dadi et al., 2021). To give an example, healthcare-associated infections are considered the main causes of mortality in the United States, and the number of cases is 1.7 million, and the diseases cause about 99,000 fatalities annually, with up to USD 33 billion spent annually on unnecessary medical expenses (Irek et al., 2018). The issue of hospital-acquired infections is very high globally and the most significant rates of this condition are observed in the Eastern Mediterranean and South-East Asia, which is why the development of powerful prevention and surveillance policies is urgent (Alkhowaiter et al., 2024).

**The Continuum of Care**

This spectrum covers both before and after admission care where medication-related issues can be of great importance and contribute to the patient becoming vulnerable to HAIs (Orlando et al., 2020). Pharmacists can positively influence the reduction of such a threat by optimizing pharmacotherapy,

observing adverse drug reactions, and patient education to achieve medication compliance during the treatment process (Sandu et al., 2025). This holistic practice will make sure the medicine regimens are safe and effective with a minimal risk of drug-related complications predisposing patients to infectious events. As an example, improper antibiotic prescriptions can be among the causes of antimicrobial resistance, which is a significant contributor to the prolongation of HAIs (Haque et al., 2020; Imarenezor et al., 2021).

In addition, it is important that the judicious use and administration of prophylactic antibiotics under the guidance of antimicrobial stewardship programs can be the most crucial in preventing a surgical site infection and other procedure-associated HAIs (Sartelli et al., 2024). In addition, pharmaceutical approaches are also directed at the development and introduction of anti-biofilm measures, such as new antimicrobial agents and anti-microbial coating of medical devices, to directly affect the persistence and spread of biofilm-associated pathogens (Abdelhamid and Yousef, 2023; Maillard and Centeleghe, 2023). This proactive engagement points out to the growing role of clinical pharmacists in the prevention and control of infections, that has moved past traditional dispensing to all-encompassing patient care management. It involves an active role in infection control committees, role in policy-making, and evidence-based recommendations related to antimicrobial use and infection prevention measures (Sartelli et al., 2023).

**Admission and Inpatient Stay**

Patients are susceptible to HAIs, especially during the admission and inpatient stay, because of a variety of factors, such as invasive medical procedures, weakened immune system, and extended exposure of the patient to healthcare facilities. The presence of the high frequency of the use of indwelling medical devices also contributes to the risk by being the common locations of biofilm development and subsequent infections (Khardori & Yassien, 1995). Pharmacists can reduce these risks by ensuring that they carefully reconcile medications, use antimicrobials to prevent their resistance, and educate patients (Kohl, 2020).

They have the knowledge to make sure that the antibiotics are selected, dosed, and terminated properly, which is essential to avoid resistance and maximize the final results of treatment, as well as give important information about the correct use of medications and the possible complications. Furthermore, the pharmacists are actively engaged in the multidisciplinary rounds, which offer expert opinion regarding the interaction of drugs, adverse effects, and optimization of medication regimes to improve patient safety and therapeutic efficacy (Zarah et al., 2025). They are also involved in overseeing the level of therapeutic drugs and modifying the dose to patients with a renal or hepatic impairment in order to reduce drug accumulation and possible toxicities (Sartelli et al., 2024).

Pharmacists can significantly contribute to the decrease in the overall rate of HAIs in hospitalized patients by screening high-risk groups and applying specific measures to them. They also play a leading role in the advancement of non-pharmacological measures, including device maintenance and hygienic guidelines, that are part of the prevention of biofilm development on indwelling medical devices (Kosmeri et al., 2024). This combination will make sure the strategy in dealing with HAIs is comprehensive because infection prevention in a hospital is a multidimensional concept (Dighriri et al., 2023; Pereira et al., 2022). In addition to individual patient care, the inpatient pharmacists play important roles in hospital wide programs, including the development of drug-use appraisals, adverse drug reaction management, and medical rounding, all of which have been proven to reduce mortality in patients (Brazeau et al., 2009).

**Transitions of Care**

The patients going through the process of transfer to another healthcare environment are more vulnerable to medication errors and complications, such as hospital readmissions (Stranges et al., 2020). Pharmacists play a crucial role in filling these gaps by adopting a holistic medication reconciliation strategy to identify errors and carry on with therapy to prevent possible adverse drug events and enhance the overall patient safety in these crucial phases (Alonazi et al., 2022; Delgado-Silveira et al., 2021). Such a scrupulous supervision reduces the rate of medication related issues, which would have otherwise undermined patient health and resulted in additional hospitalization. One more significant aspect of the situation is pharmacists who also advise patients on how to take medications properly and on possible side effects, which is important in the case of polypharmacy, which is a frequent issue

among patients admitted to the hospital with comorbidities (Chen et al., 2023; National Safety and Quality Health Service Standards User Guide to the Health Care of People with Intellectual Disabilities, 2024).

Their active discharge planning would ensure that patients, and in many cases, their caregivers understand their medication regimens well, reducing the number of post-discharge medication discrepancies (National Safety and Quality Health Service Standards User Guide to the Health Care of People with Intellectual Disability, 2024). This intervention is essential as it will decrease the chances of medication non-adherence and consequence risk, which lowers the chances of infection that frequently occur due to insufficiently controlled chronic diseases (Khatun et al., 2023). It was revealed that the collaboration between the pharmacists and healthcare providers with antimicrobial stewardship teams contributed to the decrease in the rates of recurrence of infections, which once again highlights the importance of the pharmacists in guaranteeing the best patient outcomes (Tasaka et al., 2024). Their central role in the creation and execution of antimicrobial stewardship programs specifically help minimize the rates of the healthcare-associated infection and the antimicrobial resistance (Elshenawy et al., 2025).

**Post-Discharge Follow-up**

After hospital discharge, the most important factor is the post-discharge follow-up that may help avoid readmissions and reduce the threat of the infection-related complications, particularly, in case of the medication-related complications. Pharmacists are also instrumental in this stage and can-do follow-up consultations, including medication therapy management services, to evaluate adherence, solve side effects, and clear any remaining medication-related questions (alobaidi et al., 2022; Weber et al., 2024). All these interventions are essential to help patients comprehend complex medication regimens, especially when using the outpatient parenteral antimicrobial therapy, to decrease the hospital readmissions and the overall patient outcomes (Stashluk et al., 2024). This has been proven by studies which indicate that discharge-based interventions led by pharmacists with a holistic approach, which involves various interventions, play a significant role in reducing readmissions (Weber et al., 2024).

This holistic intervention is not only helpful to strengthen the understandings of medication but also enables patients and their carers to sustain effective treatment to eliminate the risks of complications such as antibiotic overuse and unnecessary readmission (National Safety and Quality Health Service Standards User Guide for the Health Care of People with Intellectual Disability, 2024; Vaughn et al., 2021). This proactive bypass of the pharmacist assists in reinforcing the continuum of care and providing patients with therapeutic adherence and eliminating possible medication discrepancies, which may occur during the post-discharge phase (Zheng et al., 2024).

Moreover, pharmacists built into outpatient parenteral antimicrobial therapy programs offer expert advice on antimicrobial treatment, such as sterile compounding and maintenance of medication safety and stability and optimize patient outcomes at home (Roig et al., 2022). As an example, the pharmacist-led programs have greatly streamlined the outpatient parenteral antimicrobial therapy prescriptions prior to the hospital discharge to cover aspects like antimicrobial optimization, prescription clarification, and lab monitoring (Stashluk et al., 2024). This targeted intervention enables patients to receive proper antimicrobial treatment and reduces the chances of risks connected with improper monitoring or improper choice of drugs. Such pharmacist initiatives are able to prevent the possible harm and decrease the readmissions, especially in the case of complex outpatient parenteral antimicrobial therapy treatment (Stashluk et al., 2024).

**Medication-Related Problems (MRPs) in HAIs**

Medication-associated problems are common among patients with healthcare-associated infections, which include, but are not limited to inappropriate antimicrobial choice, improper dosage, and drug-drug interactions that can undermine the efficacy of treatment and safety of the patients. The issues tend to result in poor therapeutic outcomes, which cause not only the long duration of hospitalization but also the rise in healthcare expenditures, morbidity, and mortality (Dadi et al., 2021). The groups of hospital-acquired infections, which can be caused by multidrug-resistant organisms, are complex to manage, which requires careful medication management to prevent therapeutic failure and complications in patients (Dadi et al., 2021). The pharmacists with their knowledge of pharmacodynamics and pharmacokinetics are in a special position to diagnose and correct such

circumstances and, therefore, optimize antimicrobial regimens to align an individual patient with pathogen susceptibility profiles (Burnham et al., 2017). In addition, they actively observe possible adverse drug reactions and put in place measures to counter their effects in order to increase patient safety and tolerability of treatment. They are also engaged in antimicrobial stewardship programs, where they are crucial in limiting the use of some broad-spectrum antibiotics to reduce the resistance development and encourage the rational use of antimicrobials (Burnham et al., 2017).

**Table 1. Common Medication-Related Problems in Hospital-Acquired Infections.**

| MRP Category | Description | Clinical Impact | Pharmacy Intervention |
|---|---|---|---|
| Inappropriate antimicrobial choice | Use of ineffective or overly broad agents | Treatment failure, resistance | Stewardship review, antibiogram-guided therapy |
| Suboptimal dosing | Under- or overdosing | Resistance or toxicity | PK/PD-guided dose optimization |
| Drug–drug interactions | Enzyme inhibition/induction | Reduced efficacy, toxicity | Medication reconciliation |
| Adverse drug reactions | Nephrotoxicity, neurotoxicity | Therapy interruption | Monitoring and early detection |
| Prolonged duration | Excessive antibiotic exposure | C. difficile infection | Stop-date enforcement |

**Prevalence and Impact of MRPs in HAIs**

The issue of medication-related problems is especially widespread among patients with healthcare-associated infections, and it affects the adverse outcomes because of the complexity of the treatment of infections and the risk of drug use that is inherent in the usage of broad-spectrum antimicrobials. This encompasses issues related to the insertion of invasive equipment, which are the frequent causes of HAIs such as catheter-associated urinary tract infection and central line-associated bloodstream infection (Dadi et al., 2021). Also, the difficulty of handling these infections, which in many cases are multidrug-resistant pathogens, enhances the possibilities of medication errors and poor therapeutic response, which again increases the importance of attentive pharmacotherapeutic management. The proactive roles of pharmacists in detecting and solving such problems are essential to patient safety and effectiveness of the treatment (Okada et al., 2022; Uda et al., 2022). Their actions play an essential role in reducing the burden of antimicrobial resistance, so that proper and effective antimicrobial treatment is used with reduced exposure to drug-related issues (Gross et al., 2025).

This is particularly alert since the global concern on antimicrobial resistance is on the increase, making treatment interventions more complex and the initiative of managing medication more exact and efficient the only way to avoid the prevalent failure of treatment (Hommes and Surewaard, 2022). In fact, the rising rates of antimicrobial resistance are forcing the need to have a robust antimicrobial stewardship program, whereby the clinical pharmacists play a critical role in streamlining the practice of antibiotic prescribing to reduce the emergence of future resistance (Elshenawy et al., 2025). Such a proactive stance does not only help the individual patients to improve their treatment results but is also a part of the larger population-wide health initiatives to deal with the global menace of antimicrobial resistance (Elbehiry et al., 2025).

**Categories of MRPs Relevant to HAIs**

The medication-related issues that are relevant to HAIs can be broadly divided into those that deal with inappropriate choice of drugs, inappropriate dosages, drug-drug interaction, and adverse drug reactions. All these groups pose their own problems in the framework of the healthcare-associated infections, which require a delicate approach to pharmacotherapy. Poor choice of drugs, e.g., frequently presents in the form of broad-spectrum antibiotics instead of a narrow-spectrum agent, or the antimicrobial is one in which the causative pathogen is already resistant, thus encouraging further antimicrobial resistance (Chen et al., 2025). This misprescription not only causes treatment failure but also increases

the world-wide epidemic of antimicrobial resistance, by encouraging the development of drug-resistant strains (Chen et al., 2025). The problem of suboptimal dosing (underdosing and overdosing) can also contribute to the HAI management complications, either by failing to provide sufficient therapeutic concentrations or leading to the risk of toxicity and adverse events (FIP Seville 2022: Hospital Pharmacy, 2023).

In addition, drug-drug interactions, especially in polymedicated patients, which are typical of the hospital setting, can seriously modify the pharmacokinetics and pharmacodynamics of antimicrobials, resulting in drug ineffectiveness or increased toxicity. Lastly, the drug reactions may be adverse and mild or severe enough to require treatment to be discontinued or altered, thus extending the recovery process and adding to the cost of healthcare. These challenges demonstrate the urgency of sound medication management interventions such as an extensive approach to medication review and reconciliation to enhance antimicrobial therapy and patient outcomes during HAIs. These issues surrounding the misuse of antimicrobials, especially in the population, are a major cause of the emergence of resistance, which subsequently highlights the urgency of finding a solution to these problems, which will significantly cause 10 million deaths every year in the world by 2050 (AlShehail, 2025).

**Factors Contributing to MRPs in HAI Management**

There are a number of reasons that add to the prevalence of the medication-related issues in management of HAIs such as patient variables, complexities of antimicrobial agents, and systemic healthcare issues. Comorbid conditions, renal or hepatic insufficiencies, and old age, are patient-specific factors that can greatly change drug metabolism and excretion, therefore, requiring tailored dosage modifications to avoid therapeutic failure or toxicity (Anik et al., 2025). Moreover, due to the peculiarities of pharmacodynamics and pharmacokinetics of different antimicrobial agents and the changing nature of antimicrobial resistance, the correct choice of the drug and its dosage becomes more complex (Maji et al., 2019). The risk of medication errors and poor antimicrobial stewardship is further increased by the systemic healthcare problems, such as staffing shortages, the lack of pharmacological knowledge in healthcare providers, and poor organizational processes, which are typically centers of resistant bacteria (Machado et al., 2024). Such systemic shortcomings often lead to the later initiation of timely antibiotic treatment, inadequate antibiotic entry to infection sites, or contacts with biofilm matrices, all of which cause a treatment failure despite ostensibly proper susceptibility-directed treatment (Kuehl et al., 2019). Being able to develop new healthcare-associated infections subsequent to an initial consultation sign-off may further complicate patient management, which in most cases results in non-adherence to infectious disease recommendations and even higher mortality rates due to such pathogens as Klebsiella pneumoniae and Staphylococcus aureus (Ali et al., 2024; Takamatsu and Honda, 2023). Outside of such systemic problems, microplastic contamination of the environment also contributes substantially, but is frequently ignored in developing antimicrobial resistance in a healthcare environment (Gross et al., 2025). Microplastics may contain harmful microorganisms and antibiotic resistance genes, creating a special microbioplastic niche, which makes it easy to transfer ARGs to pathogenic bacteria via biofilm formation (Chen et al., 2025; Gross et al., 2025). The fact that even low levels of environmental antibiotic residues act to promote the selection and growth of antibiotic-resistant bacteria and resistance genes in such microplastic biofilms can further increase this problem (Joannard and Sanchez-Cid, 2024).

The same phenomenon highlights the complexity of the interaction between anthropogenic pollution and the clinical problem of antibiotic resistance, which does not just limit the direct exposure to antimicrobials but also includes environmental reservoirs (Joannard & Sanchez-Cid, 2024). This underscores the urgent necessity of considering the environment in the overall program of antimicrobial stewardship to achieve the desired outcome of combating the multidimensional drivers of resistance (Joannard & Sanchez-Cid, 2024).

**Table 2. Medication-Related Problems Across the Continuum of Care.**

| Care Stage | Common MRPs | Risk Factors | Pharmacist Role |
|---|---|---|---|
| Pre-admission | Inadequate prophylaxis | Poor guideline adherence | Protocol optimization |

| | | | |
|---|---|---|---|
| Inpatient care | Dosing errors, interactions | Polypharmacy, organ dysfunction | TDM, daily review |
| Transitions of care | Medication discrepancies | Poor communication | Medication reconciliation |
| Post-discharge | Non-adherence, toxicity | Complex regimens | Counseling, follow-up |

**Disease-Based Clinical Pharmacy Review of HAIs**

This part is going to offer a disease-based clinical pharmacy overview of particular hospital-acquired infections, examine the difficulties in their pharmacological treatment, and find an opportunity to conduct clinical pharmacy interventions. The review will be dedicated to frequent HAIs such as ventilator-associated pneumonia, catheter-associated urinary tract infections, central line-associated bloodstream infections, and surgical site infections along with the microbiological epidemiology and resistance patterns related to each one of them (Dadi et al., 2021; Sandu et al., 2025). It discussed the usefulness of antibacterial envelope as a prospective intervention in minimizing device-associated infections, including those associated with cardiovascular implantable electronic device (Dadi et al., 2021). Moreover, the discussion will cover the new therapeutic options as well as the inclusion of the precision medicine methods including pharmacogenomics to maximize antimicrobial choice and dosing to achieve better patient outcomes during HAIs.

The growing issue of microplastic contamination in healthcare settings will also be discussed in this review, its role in spreading antimicrobial resistance, specifically, through the hospital wastewater, and its impact on the infection control measures (Gross et al., 2025; Tuvo et al., 2023). The review explored the way these environmental microplastics affect hospital microbiomes, which may form new reservoirs of antibiotic-resistant bacteria and, therefore, change the dynamics of transmission within the clinical environment (Gross et al., 2025). These and other kinds of environmental sensitivities are becoming critical towards the development of holistic antimicrobial stewardship programs which are no longer limited to clinical interventions but also include environmental determinants of resistance (Koizumi and Maruyama, 2023).

**Impact of Clinical Pharmacy Interventions on MRPs and HAI Outcomes**

Clinical pharmacists can reduce the occurrence of medication-related issues and enhance patient outcomes in hospital-acquired infections by being part of antimicrobial stewardship programs (Alkhaldi et al., 2022; Dighriri et al., 2023). Their knowledge of pharmacokinetics, pharmacodynamics and trends of antimicrobial resistance will help to optimize drug choice, dosage and monitoring, thus reducing the adverse drug events and occurrence of additional resistance (Khan et al., 2024). Further, pharmacists also play an important role in patient education to ensure compliance with complex antimicrobial regimens and minimize chances of treatment failures or readmissions (Ioannou & Koferidis, 2025). They also engage in interdisciplinary rounds actively, which is useful to give their insights on the possible drug interactions and to advise on the adjustment of the therapeutic course, referring to the real-time clinical information and microbiological findings.

Specifically, infectious disease pharmacists have the role of evaluating interventions regarding infectious diseases, assessing the types of interventions, their acceptance by physicians, and the amount of their potential cost savings, including direct (e.g., replacing intravenous with oral antibiotics) and indirect (e.g., preventing extended hospital stays) savings (AlShehail, 2025). They are essential in antimicrobial stewardship programs as they are the primary contributors to global health against antimicrobial resistance, as they have taken part in developing and updating antimicrobial guidelines (Elshenawy et al., 2025). Moreover, clinical pharmacists also play a central role in the introduction of hospital antimicrobial stewardship initiatives and their assessment, which needs to be effective in the control of healthcare-associated infections and the struggle against antimicrobial resistance (Alfahmi et al., 2023; Hadi et al., 2024). They are involved in using technological advances to enhance better infection prevention and control, through the introduction of rapid diagnostic, and modern cleaning habits to limit bacterial resistance (Elbehiry et al., 2022).

**Strategies for Optimizing Medication Use to Prevent and Manage HAIs**

Antimicrobial Stewardship Programs are the systematic programs aimed at maximizing the use of antimicrobials, enhancing patient outcomes, and minimizing the incidence of antimicrobial resistance (Tasaka et al., 2024). Such programs include a multidisciplinary strategy, which implies the selection of the apposite antimicrobials, dose, time, and de-escalation depending on the diagnosis stewardship and patient-specific considerations (Bankar et al., 2022). Such programs play a vital role in alleviating medication-related issues and enhancing the overall patient outcomes in the situation involving hospital-acquired infections, particularly with the increased problem of antibiotic resistance (Aladekoyi et al., 2024). The process of stewardship requires the ongoing cycle of monitoring, intervention, and review, and in many cases, the work of committed clinical pharmacists (AlShehail, 2025; Burnham et al., 2017). These pharmacists use electronic systems to measure interventions and quantify them into cost savings, whereby such electronic systems can be adjusted to the institutional measures and product peculiarities (AlShehail, 2025). In different countries, like the USA, UK or Japan, pharmacists apply diverse antimicrobial stewardship measures and evaluate how much they affect such metrics as the length of stay, Clostridioides difficile infection rates, and the cost of antimicrobial use (Elshenawy et al., 2025). The effectiveness of these initiatives is hinged on a strong surveillance of antibiotic use and resistance trends, and they can respond to the threats accordingly (Aladekoyi et al., 2024). The inclusion of antimicrobial stewardship programs with the efforts in infection prevention and control is one of their primary elements since a comprehensive approach to infection control has proven more effective than the one-sided approach in reducing hospital-acquired infections (Slikke et al., 2023).

**Drug Reconciliation and Review**

Having clear medication reconciliation and medication review procedures is crucial in detection and correction of discrepancies in patient medication regimes especially at transitional care levels, thus utilizing potential adverse drug events and enhancing patient safety. These activities include a systematic check of a drug the patient is taking at the moment against newly prescribed drugs, and this procedure is necessary and accurate in all medical facilities (National Safety and Quality Health Service Standards User Guide for the Health Care of People with Intellectual Disability, 2024).

This careful examination can be used to eliminate the possibility of medication errors, e.g., duplications, omissions, or wrong dosages, which are especially important in patients prone to HAIs or already infected (Cardenas et al., 2021). Drug-drug interaction or contraindication causing the aggravation of an infection or loss of treatment effectiveness can be detected through the detailed review of medications by pharmacists. They are also crucial in making sure that antimicrobial treatment is optimized against certain pathogens, as well as patient comorbidities, thus reducing the chance of failure in treatment and developing resistance. Moreover, the involvement of medication histories, along with patient education on the correct intake and the possible side effects, is imperative in improving patient compliance and minimizing readmission rates related to medication-related issues (Tasaka et al., 2024). These strategies of proactive medication management play a critical role in the prevention of hospital-acquired infections, especially by decreasing the odds of antibiotic-associated adverse events such as Clostridioides difficile (McGregor et al., 2021). In addition to avoiding direct unfavorable outcomes, such careful reviews help prevent infections through the proper application of prophylactic antimicrobials, particularly during surgery, thus minimizing morbidity of HAI-related surgical site infections and other adverse events. The role of the pharmacist also includes examining the suitability of the empirical antibiotic treatment and making sure that it is consistent with the local antibiograms and institutional guidelines to limit the excessive use of broad-spectrum antibiotics (Grant et al., 2021). Also, pharmacists are essential in medication reconciliation when patients are transferred to different hospitals to reduce adverse drug events and the acquisition of multidrug-resistant organisms by giving accurate medication lists and proper prescriptions (Mercuro et al., 2022).

**Table 3. Clinical Pharmacy Strategies to Reduce MRPs in HAIs.**

| Strategy | Target Problem | Key Actions | Outcome |
|---|---|---|---|
| Antimicrobial stewardship | Inappropriate use | Audit and feedback | Reduced resistance |
| Therapeutic drug monitoring | Toxicity, underexposure | Serum level adjustment | Improved safety |

| | | | |
|---|---|---|---|
| Medication reconciliation | Errors at transitions | Accurate medication lists | Fewer readmissions |
| Patient education | Non-adherence | Counseling and follow-up | Better outcomes |
| Interdisciplinary rounds | Fragmented care | Team-based decisions | Reduced MRPs |

**Patient Education and Counseling**

Patient education and counseling cannot be done without as they are essential to guarantee that patients have an idea about their medication regimens, to encourage patients to adhere, and to be aware of possible side effects, in particular, regarding the use of antibiotics (Alghanim et al., 2025). It is especially crucial in preventing hospital-acquired infections because patient knowledge of correct hygiene, medication storage as well as the need to take the course of antibiotics completely can help to minimize the risk of the spread of the infection and the emergence of antibiotic resistance (Gollan et al., 2019). In their turn, pharmacists can play a role in safer prescribing and dispensing by offering the necessary information on medications, such as antibiotics, to patients and medical professionals (Pereira et al., 2022). They enable the patient to be a fully active agent in their health care and promote a joint method in the management of drugs and infection prevention (Alonazi et al., 2022).

This individualized counseling is then expanded to the severe importance of taking the recommended courses of antibiotics, despite the improvement of symptoms, to avoid the development of the antibiotic-resistant bacteria (Sen et al., 2023). Also, pharmacists can inform patients on how to dispose of unused antibiotics to avoid contamination of the environment, which can be added to the problem of antibiotic resistance at the global scale (Aladekoyi et al., 2024). In addition, it is possible to educate patients about the possible adverse drug reactions to antibiotics, including gastrointestinal disturbances or allergic reactions and promptly report any such symptoms, thus intervening and preventing serious complications (Arviani et al., 2025).

**Role of the Clinical Pharmacist in HAI Management**

Clinical pharmacists should lead antimicrobial stewardship programs that are essential to reduce the increasing levels of antibiotic resistance, which is a major cause of hospital-acquired infections (Maji et al., 2019). The strategies that pharmacists put into practice include maximizing the prescribing of antibiotics, adverse drug reactions tracking, and training health professionals about how to use antimicrobials (Suh et al., 2021). They also participate in the development and enforcement of institutional antimicrobial policies, prospective audit and feedback, and formulary restrictions leadership in order to encourage reasonable choice of antimicrobials (Bakri et al., 2022). This proactive strategy greatly decreases the abuse of antibiotics hence decreasing selective pressure on bacterial populations and conserving the efficacy of the available antimicrobial agents. These types of clinical pharmacist interventions have been well documented in literature as essential to reduce cases of unnecessary antibiotic use and to inform a patient and other healthcare professionals on how to use antibiotics correctly (Sakeena et al., 2018).

Such programs are also crucial in helping patients to learn about infection prevention and the necessity to take the antibiotic medication as prescribed (Guðnadóttir et al., 2013). The pharmacists also participate in the population health promotion to create awareness on antimicrobial resistance and proper use of antibiotics, which influence the behavior of patients both in and outside the hospital (Balea et al., 2025). They play a crucial role as liaisons between prescribers, nursing personnel, and patients, to organize more effective approaches in order to supplement antibiotic stewardship by being directly involved in drug choices, dosage, and administration processes (MQ, 2018). They can be used to optimize the dosage schedule, such as extended-interval dosing or continuous infusions, to improve treatment results and minimize the incidence of drug toxicity due to their pharmacokinetics and pharmacodynamics (Zhou et al., 2023).

**The role of pharmacist in determining and solving MRPs**

In the systematical review of the medication regimens, the clinical pharmacists play a crucial role in detecting and addressing medication related issues, which can easily develop into hospital-acquired infections or complicate the management process. This involves careful evaluation of the antibiotic prescriptions in terms of appropriateness, dosage, frequency, route and duration to ensure that they are

based on evidence-based guidelines and patient specific factors to minimize adverse drug reactions and maximize therapeutic efficacy (Kuruvilla et al., 2023). They carefully determine possible drug-drug interactions, contraindications, and allergies that may cause adverse events or therapeutic failures, and accordingly, prevent complications proactively (Mas-Morey et al., 2017).
In addition, pharmacists are also using their knowledge to carry out detailed medication therapy management, which is centered on optimization of antibiotic therapy according to patient-specific factors such as renal and hepatic clearance, infections site, and microbial susceptibility pattern (Li et al., 2024). They also consider the results of monitoring results of therapeutic drugs to vary the dosages, especially those with narrow therapeutic index antibiotics, to achieve optimum drug levels at low doses (Muhammad, 2024). This high level of supervision will guarantee an effective and safe use of antibiotic therapy by both the patient and the pathogen, a two-fold goal that is very important in reducing the occurrence of HAI and enhancing the patients outcome. Their important role is further seen in their collaboration with interdisciplinary healthcare teams in order to overcome the identified medication discrepancies so that they may promote a holistic approach to patient care that would reduce the risk of adverse drug events and treatment failures significantly. Pharmacists could act by suggesting antimicrobial bug/drug mismatch corrections, optimization of the antimicrobial therapy according to the patient features, and de-escalation of broad-spectrum antimicrobials to narrow-spectrum agents in suitable cases (AlShehail, 2025).

It is revealed that these interventions could greatly decrease healthcare expenses and enhance the patient outcomes in the management of infectious diseases (AlShehail, 2025). That is why interdisciplinary Collaboration in the Prevention and Management of HAI is needed. The prevention and management of healthcare-associated infections require a strong interdisciplinary strategy, where clinical pharmacists are viewed as the part of the healthcare team, with physicians, nurses, and other experts (Zarah et al., 2025). Being knowledgeable experts in pharmacotherapy, especially on the use of antimicrobial agents, they can offer invaluable feedback on infection control and antimicrobial stewardship and patient-centered treatment. Pharmacists also play a role in this teamwork space as they can participate in ward rounds, provide specialized guidance on the choice of drugs, dosage changes, and possible drug interactions, and optimize the treatment results (Mongardon and Vincent, 2024).
They can also be central to the provision of education to the rest of the healthcare team on the recent guideline on antibiotic use and infection control precautions to maintain a cohesive method of patient safety (Schmid et al., 2022). Such joint paradigm is critical to conducting multifaceted measures, including infection monitoring, environmental hygiene, and compliance with standard practices of infection control, which is of significant importance to reduce the spread of HAI (Bakri et al., 2022). They are also skilled in the assessment of new antimicrobial agents and disinfection procedures and can guarantee the implementation of practices that are effective in countering multidrug-resistant pathogens and biofilm-associated infections (Bouhrour et al., 2024; Maillard and Centeleghe, 2023).

## Challenges and Future Directions

### Barriers to Effective MRP Management in HAIs

Although the role of pharmacists is identified in reducing HAIs, various systemic and practical obstacles to optimal management of medication-related issues have been observed in this scenario. Among the major problems, there is the rising trend of antimicrobial resistance, which leads to a rise in the costs of treatment and the extension of the length of stay (Imarenezor et al., 2021). Besides, issues related to treatment of infections caused by multidrug-resistant bacteria which in most cases exist in recalcitrant biofilms further complicate the therapeutic efforts and increase the risk of treatment failure (Abdelhamid and Yousef, 2023). This issue is made worse by the ongoing development of new resistance and the lack of availability of many new antimicrobial agents in the pipeline, such that successful therapeutic decision-making becomes more difficult (Maji et al., 2019).
Also, the complex interdependence of global environmental pollution, including microplastics, and the emergence of antimicrobial resistance adds another level of complexity that encourages the formation and transmission of drug-resistant bacteria outside the hospital setting (Gross et al., 2025). This underscores the urgency of a thorough knowledge of the environmental factors that lead to antimicrobial resistance that requires innovative methods of preventing and controlling infections (Gross et al., 2025). The next obstacle is a strong one due to the global unequal distribution of health resources and

infrastructure, a lack of access to quality diagnostic equipment, more advanced treatment options, and trained pharmacy staff in the majority of states, which prevents complete attempts to control the infection and manage the medication (Sartelli et al., 2023). The differences are what lead to the suboptimal stewardship of antimicrobials and elevated incidences of healthcare-associated infections, especially in the environments with a low access to rapid diagnostics and microbiology services that can help to make the right choice regarding antibiotics (Sandu et al., 2025; Sartelli et al., 2024).

**New Threats and New Therapeutic Strategies.**

The growth of multidrug-resistant and even pan-drug resistant bacterial types will require the investigation of new therapeutic directions to address HAIs (Tozzo et al., 2022). This necessity promotes the investigation of alternative non-antibiotic antimicrobial agents, including bacteriophages and antimicrobial peptides as well as a combination therapy, which will enhance the effectiveness of treatment and reduce the further development of resistance (Kadirvelu et al., 2024). Other perspectives on future directions in the fight against persistent infections are the in-depth study of bacterial biofilms, their underlying genetic and physiological processes of their formation, and resistance to traditional therapies (Abdelhamid and Yousef, 2023). These are new initiatives such as creating anti-biofilm agents based on natural products and considering phage therapy as another option to unsuccessful antibiotic therapy of multidrug-resistant bacteria (Lu et al., 2019; Sandu et al., 2025). Furthermore, the incorporation of innovative technologies in the diagnostic procedure, i.e. genomics and proteomics, is essential to the accurate pathogen identification and the creation of individual-based treatment plans, particularly when it comes to life-threatening infections (Sandu et al., 2025).

Moreover, the introduction of AI and machine learning algorithms will transform the field of diagnostics and treatment by simplifying the process of detecting pathogens, forecasting antimicrobial resistance, and optimizing the treatment course (Elbehiry and Abalkhail, 2025; Sandu et al., 2025). Such technological improvements are currently promising to break most of these limitations in the field of infection control, and a way forward to more specific and effective interventions against antibiotic-resistant pathogens. These computational tools may be used in processing large volumes of clinical, microbiological, and patient data to forecast epidemics and predict vulnerable patients and to shape tough infection prevention and control measures (Sandu et al., 2025). Moreover, the study of new anti-biofilm approaches, such as the process of surface modification of medical equipment and quorum-quenching agents, is essential due to the limitations of the current treatment of biofilm-related diseases (Mayorga-Ramos et al., 2024; Sharma et al., 2023).

## Conclusion

The issue of the medication-related issues is endemic along the continuum of care in patients with hospital-acquired infections and acts as a serious but avoidable cause of treatment failure, toxicity, antimicrobial resistance, and unnecessary healthcare expenditure. Multidrug-resistance causing pathogens, biofilm formation on medical equipment, invasive interventions, and regular changes in care facilities make HAI management complicated and contribute to the probability of using inappropriate antimicrobials and medication errors. As shown in this review, MRPs are a frequent occurrence in all the levels of care, such as the initiation of empiric therapy, inpatient care, discharge planning, and even during the post-discharge follow-up. Clinical pharmacists can be in the front line to prevent these risks by conducting comprehensive antimicrobial stewardship, antimicrobial optimization, therapeutic drug surveillance, deprescribing of unnecessary medications, and patient-centered education. It has always been demonstrated that pharmacist-led interventions decrease the incidence of adverse drug events, enhance adherence to guidelines, decrease hospital length of stay, readmission rates, and achieve significant cost reductions. Moreover, the implementation of clinical pharmacists in antimicrobial stewardship and multidisciplinary care groups enhances infection prevention and restrains the development of antimicrobial resistance. In spite of these advantages implementation is still threatened by limited resources, disjointed care systems, and increased antimicrobial resistance due to both clinical and environmental aspects. The further strategies have to focus on standardized medication reconciliation during transitions of care, increased pharmacist participation in infection control projects, and the integration of new technologies, including rapid diagnostics, pharmacogenomics, and decision support based on artificial intelligence. To sum up, integrating clinical pharmacy services throughout

the spectrum of care is needed to decrease medication-related issues and enhance patient outcomes in terms of hospital-acquired infections.

**Conflict of Interest**
The authors declare they don't have any conflict of interest.

**Author contributions**
The first drafts of the work are written by the original author and the cross-ponding author's supervisor. Each author wrote a portion of the manuscript, collected data, edited it, created tables, and was given permission to submit it to a journal for publication.

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