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Hospital-Acquired Infections in the Era of Antimicrobial Resistance: From Infection Prevention to Precision Infection Control

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ABSTRACT: The problem of Hospital-Acquired Infections (HAIs) is a major issue in contemporary health care systems, especially with the speed at which antimicrobial resistance (AMR) is developing. The emergence of multidrug-resistant (MDR) pathogens has made it more difficult to treat and use standard antimicrobials, resulting in longer hospital stays, more expensive health care, and increased mortality. Resistant organisms like methicillin-resistant *Staphylococcus aureus*, vancomycin-resistant *Enterococcus*, and carbapenem-resistant *Enterobacteriales*, *Pseudomonas aeruginosa*, and *Acinetobacter baumannii* are frequently associated with major HAIs, including catheter-associated urinary tract infections, central line-associated bloodstream infections, ventilator-associated pneumonia, surgical site infections, and *Clostridioides difficile* infections. To manage HAIs effectively, a multifaceted strategy involving antimicrobial stewardship programs, advanced surveillance techniques and infection prevention measures is essential. Innovative methodologies such as rapid molecular diagnostics, whole genome sequencing, AI, digital healthcare platform and personalised antimicrobial therapy have been introduced as recent developments in precision infection control. These technologies allow for predicting resistance, early detection of pathogens, outbreak detection and targeted therapeutic interventions. In addition, novel antimicrobial strategies such as bacteriophage therapy, antimicrobial peptides, monoclonal antibodies, microbiome-based strategies and nanotechnology-enabled drug delivery systems offer promising opportunities for combating resistance. But these developments come with challenges, including low rates of antibiotic discovery, global disparities in health care resources, a lack of precision approaches and validation problems in the clinic. This review identifies the present burden of HAIs during the

AMR era, discusses major strategies for infection prevention and antimicrobial stewardship, and explores the role of precision infection control technologies in patient safety. Combined with the application of AI, smart healthcare systems and One Health approaches, future work that integrates genomic surveillance could offer sustainable solutions for controlling HAIs and minimizing the global impact of antimicrobial resistance.

1. INTRODUCTION

Nosocomial infections, or hospital-acquired infections (HAI), are infections acquired during the course of the healthcare delivery and present or incubating at the time of admission to the hospital. Typically, these infections develop 48 hours or more after hospital admission or shortly after discharge following medical procedures. Examples of HAI include bloodstream infections, ventilator-associated pneumonia, catheter-associated urinary tract infections (CAUTIs), surgical site infections and invasive medical device-associated infections. They continue to be one of the largest issues concerning patient safety as they contribute to morbidity, mortality, longer hospital stays, and higher health care costs globally (Horan et al., 2008; Peleg & Hooper, 2010). Despite incredible growth in medical technology and infection control, the global burden of HAIs is growing all the time. It is especially hazardous for critically ill patients, elderly people, immunocompromised patients, and people who need to be hospitalized for a long time. Intensive care units (ICUs) are high-risk areas where invasive procedures are performed and antibiotics are regularly used, which increases the risk of infectious organisms being transmitted. Common pathogens associated with HAIs include *Staphylococcus aureus*, *Enterococcus faecium*, *Klebsiella pneumoniae*, *Escherichia coli*, *Pseudomonas aeruginosa* and *Acinetobacter baumannii*. The pathogens are associated with a significant number of hospital-associated infections and play an important role in health-care cost and clinical outcomes (Abban et al., 2023; Peleg & Hooper, 2010).

In addition, the use of widely-used antibiotics has become less effective because of antimicrobial resistance (AMR), which has further complicated the management of HAIs. AMR is when microorganisms develop resistance to an antimicrobial drug to which they were once susceptible. Inappropriate and excessive antibiotic use, prolonged hospitalization, use of invasive devices and inadequate infection control practices contribute to the rapid development and dissemination of resistant organisms in health care facilities. The ESKAPE pathogens such as *Enterococcus faecium*, *Staphylococcus aureus*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*, *Pseudomonas aeruginosa* and *Enterobacter* species are of special interest because these pathogens are very resistant to a variety of antibiotics and are known to cause hospital-acquired infections worldwide that are difficult to treat (Santajit & Indrawattana, 2016; Abban et al., 2023). HAI and AMR are intricately connected and have become a serious public health problem on a global scale with potential impact on patient safety and healthcare sustainability. Routine infection control procedures, such as hand care, environmental cleaning, sterilisations and isolation procedures are still important and are frequently necessary, but often inadequate for dealing with the growing challenge of highly resistant, multi-drug-resistant pathogens. The advent of molecular diagnostics, genomic surveillance, artificial intelligence, predictive analytics, and precision medicine have ushered in a new paradigm in infection control: precision infection control, in which disease prevention and treatment are customized based on the risk of each patient, the characteristics of the pathogen, and real-time data on the epidemiology of the disease. These strategies could enhance infection control, antimicrobial stewardship, and decrease the burden of resistant healthcare-associated infections (Cocker et al., 2024). This review aims to offer a thorough overview of HAI in the era of antimicrobial resistance, explore the epidemiology and clinical relevance of MDR pathogens and review current infection prevention and antimicrobial stewardship measures, while emphasizing new precision infection control measures that have the potential to enhance patient outcomes and bolster healthcare systems.

2. EPIDEMIOLOGY, RISK FACTORS, AND PATHOGENESIS OF HOSPITAL-ACQUIRED INFECTIONS

2.1 Epidemiology

Hospital-acquired infections (HAIs) are still one of the common preventable causes of morbidity and mortality in hospitals all over the world. HAIs are a significant public health problem which affects hundreds of millions of patients yearly, according to WHO. The incidence of HAIs is different in various countries from about 5-10% in high-income countries to more than 15% in many low and middle-income countries where lack of infection-control resources, overcrowding and poor

surveillance contribute to higher rates of infection (World Health Organization [WHO], 2022; Magill et al., 2018). The higher the number of invasive devices used, such as mechanical ventilation, urinary catheterization and central venous catheterization, the higher the risk of HAIs, especially in intensive care units (ICUs). These interventions carry a risk of bloodstream infections, ventilator-associated pneumonia, and catheter-associated urinary tract infections. In addition to their clinical implications, HAIs extend hospital stays, drive up health care costs and contribute to a substantial rise in the death rate, especially with elderly and immunocompromised patients (Magill et al., 2018; Cassini et al., 2016).

Table 1. Global Epidemiological Characteristics of Hospital-Acquired Infections.

Parameter	Observation
Global prevalence	Approximately 5–15% of hospitalized patients
Highest-risk setting	Intensive Care Units (ICUs)
Most affected patients	Elderly, critically ill, immunocompromised patients
Major consequences	Increased morbidity, mortality, prolonged hospitalization
Economic impact	Increased healthcare expenditure and resource utilization

2.2 Major Types of Hospital-Acquired Infections

Most healthcare-associated infections (HAIs) are caused by a few types. Catheter associated urinary tract infection (CAUTI) is one of the most prevalent and occurs after a urinary catheter is left in place for an extended period of time. Central line-associated bloodstream infections (CLABSI) occur when microorganisms colonize intravascular catheters and get into the bloodstream. Ventilator-associated pneumonia (VAP) is the pneumonia that develops in patients who are mechanically ventilated and is linked to high mortality rates. Surgical site infections (SSIs) are still a frequent complication after surgery, especially after abdominal, orthopedic, and cardiovascular surgeries. Clostridioides difficile infection (CDI) is another major HAI which occurs when patients have been taking antibiotics for a long period of time with resulting severe antibiotic-associated diarrhea and colitis. These infections are responsible for the majority of hospital admissions, length of hospital stay, and associated health care expenses associated with HAI (Centers for Disease Control and Prevention [CDC], 2024).

Table 2. Major Multidrug-Resistant Pathogens Associated with HAIs.

Pathogen	Major Resistance	Common Hospital Infections
MRSA	Methicillin resistance	Surgical site infection, bloodstream infection, pneumonia
VRE	Vancomycin resistance	Bloodstream infection, urinary tract infection
CRE	Carbapenem resistance	Sepsis, pneumonia, urinary tract infection
<i>Pseudomonas aeruginosa</i>	Multidrug resistance	VAP, burn wound infection, bloodstream infection
<i>Acinetobacter baumannii</i>	Extensively drug-resistant	ICU pneumonia, wound infection, bacteremia

2.3 Common Multidrug-Resistant Pathogens

Multidrug-resistant (MDR) bacteria are becoming commonplace and making the prevention and treatment of HAIs more difficult. Methicillin-resistant Staphylococcus aureus (MRSA) continues to be a major cause of bloodstream infection, pneumonia, and surgical site infections (SSIs). Vancomycin-resistant Enterococcus (VRE) is a significant cause of healthcare-associated bacteremia and urinary tract infections (UTI), especially in immunocompromised patients. Carbapenem-resistant Enterobacterales (CRE) are considered to be among the most serious antimicrobial-resistant pathogens due to their resistance to several classes of antibiotics and the lack of therapeutic choices. Similarly, ventilator-associated pneumonia, bloodstream infection and wound infection in the ICU are common infections by multidrug-resistant *Pseudomonas aeruginosa* and *Acinetobacter baumannii* in patients. They are associated with persistent outbreaks and poor clinical outcomes due to their

resistance to hospital environment, and their ability to rapidly acquire resistance genes (Bonomo et al., 2018; Tacconelli et al., 2018).

2.4 Risk Factors and Mechanisms of Infection

The development of HAIs is due to a complicated relationship between vulnerable patients, resistant bacteria, and the health care environment. Factors associated with the patient include previous antibiotic use, poor nutritional status, prolonged hospital stay, immunosuppression, chronic diseases, and advanced age. Invasive medical devices create direct entry points for microorganisms, and greatly raise the risk of infection. Persistent infections arise from bacteria surviving host immune defenses and antimicrobials by forming biofilms on implants, devices or catheters. A mechanism for rapid dissemination of antimicrobial resistance genes among bacterial populations is the process of horizontal gene transfer via conjugation, transformation and transduction. Furthermore, over- or underusing antibiotics can have a negative impact on the selection of organisms that can survive and spread in healthcare environments. It is important to understand these mechanisms in order to develop effective infection prevention and precision infection-control strategies (Hall & Mah, 2017; Munita & Arias, 2016).

3. INFECTION PREVENTION AND ANTIMICROBIAL STEWARDSHIP

3.1 Standard Infection Prevention Measures

Hospital-acquired infections (HAIs) and the spread of antimicrobial-resistant organisms (AMROs) are the bases of effective infection prevention and control (IPC) practices. Hand hygiene is the most important and cost-effective preventive measure. Hand cleaning before and after patient contact has a major impact on reducing microbial transmission between health care workers, patients and the health care environment. Hand hygiene facility access, ongoing monitoring, and educating health workers to encourage compliance are currently recommended (Glowicz et al., 2023). Environmental cleaning and disinfection is also crucial as many resistant pathogens can survive on hospital surfaces and medical equipment. Environmental reservoirs of infection are minimized by regular cleaning of patient-care areas, by using the right surgical instrument sterilization, and by using effective disinfection of reusable instruments. Use of PPE (gowns, gloves, masks and eye protection) and use of appropriate isolation precautions will prevent transmission of infectious agents, especially in the event of an outbreak of a multidrug-resistant organism (MDRO) (Siegel et al., 2007).

Table 3. Major Infection Prevention Strategies in Healthcare Settings.

Infection Measure	Prevention	Purpose	Clinical Impact
Hand hygiene		Prevents transfer of microorganisms through healthcare workers	Reduces HAI transmission
Environmental cleaning		Removes microbial contamination from surfaces	Limits pathogen reservoirs
Sterilization and disinfection		Eliminates microorganisms from instruments and equipment	Prevents device-associated infections
Personal protective equipment		Provides barrier protection	Reduces occupational and patient exposure
Isolation precautions		Prevents spread of resistant pathogens	Controls outbreaks

3.2 Hospital Infection Prevention Programs

Infection prevention programs within a hospital are a structured approach to the surveillance, prevention and control of HAIs. These are programs that involve ongoing infection surveillance, microbiological monitoring and trends analysis of infection within healthcare facilities. Surveillance systems are used to alert to the presence of new resistant organisms, to pinpoint outbreaks early on and to measure the impact of prevention measures. Outbreak investigation is a pivotal element of infection control programs that will include the identification of the source of the infection, the pathway of spreading infection, measures to be taken to contain the outbreak, and strategies to prevent the outbreak from reoccurring. Education of the health-care workers and frequent training sessions increase awareness about hygiene practices, antimicrobial resistance,

as well as safe procedures in patient care. Additionally, audit and feedback, infection-control committees and performance monitoring are key components of quality improvement programs that support institutional safety culture (World Health Organization [WHO], 2022).

3.3 Antimicrobial Stewardship Programs (ASP)

Antimicrobial stewardship programs (ASPs) are multidisciplinary strategies designed to optimize antimicrobial use, maximize patient outcomes, and minimize unnecessary antimicrobial consumption. These programs are designed to assure proper route, dosage, duration, and selection of antibiotic usage. The inappropriate use of antibiotics is one of the biggest drivers of antimicrobial resistance and stewardship programs are crucial in limiting unnecessary antibiotic exposure. Prospective audit and feedback, antibiotic restriction policies, clinical treatment guidelines and rapid diagnostic support are all key components of ASPs. Antimicrobial de-escalation is the process whereby the clinician recognizes the pathogen and changes a broad-spectrum antibiotic treatment to a more targeted approach. By monitoring antibiotic use with defined daily doses and antibiotic resistance surveillance, the effectiveness of antibiotic programs can be assessed and areas for improvement can be identified (Baur et al., 2017). The benefits of successful ASP implementation include decreased antibiotic consumption, decreased resistance rates, better clinical outcomes and lower healthcare costs. Stewardship programs can be integrated with infection prevention programs for a more complete strategy to control HAIs in the era of antimicrobial resistance (Barlam et al., 2016).

Table 4. Core Components and Outcomes of Antimicrobial Stewardship Programs.

ASP Component	Strategy	Expected Outcome
Appropriate antibiotic prescribing	Selection of correct drug, dose, and duration	Improved treatment effectiveness
Prospective audit and feedback	Regular review of antibiotic therapy	Reduced inappropriate use
Rapid de-escalation	Switching broad-spectrum therapy to targeted antibiotics	Lower resistance pressure
Antibiotic consumption monitoring	Tracking antibiotic utilization trends	Improved prescribing practices
Multidisciplinary collaboration	Participation of physicians, pharmacists, and microbiologists	Better clinical outcomes

3.4 Challenges in Infection Prevention

Although there have been improvements in infection-control practices, there are still a number of challenges that persist, all of which hinder the effective prevention of HAIs. Inadequate hand hygiene and isolation practices are still a significant risk, especially caused by workload pressures, lack of awareness or training. Limited resources—such as low staffing levels, a shortage of infection control personnel, and inadequate laboratory support—pose major hurdles, particularly in low- and middle-income countries. The continuous emergence of resistant organisms further complicates matters, as traditional prevention measures may prove ineffective against highly adaptable pathogens. Furthermore, a lack of diagnosis and access to rapid microbiological testing can lead to delayed or inappropriate antibiotic usage and delayed initiation of effective treatment. Therefore, advanced diagnostics, digital surveillance, and precision-based infection-control strategies must be integrated into future HAI prevention frameworks (Zingg et al., 2015).

4. PRECISION INFECTION CONTROL: EMERGING TECHNOLOGIES AND FUTURE STRATEGIES

4.1 Rapid Diagnostic Technologies

Hospital-acquired infections (HAIs) and antimicrobial resistance (AMR) are becoming increasingly complex, necessitating speedy and accurate diagnostic approaches. Pathogen identification and antimicrobial susceptibility testing can take a few days using conventional microbiological techniques, possibly delaying the delivery of appropriate treatment. A new generation of molecular diagnostics has revolutionized the management of infections with the ability to identify pathogens and resistance

early on. Polymerase chain reaction (PCR) assays enable the identification of bacterial, viral and fungal pathogens in a sensitive and specific manner in just hours. Multiplex molecular platforms enable the detection of several microorganisms and resistance genes in a single clinical sample, which enhances the early decision on treatment (van Belkum et al., 2020). Pathogen characterization, outbreak investigation and surveillance of antimicrobial resistance has become a powerful tool thanks to Whole-Genome Sequencing (WGS). WGS can generate detailed genetic information, helping to uncover how a disease is transmitted and to identify new resistance mechanisms. Likewise, matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) can be used for microbial identification using protein fingerprinting, and is being increasingly adopted in the clinical microbiology laboratory. Point-of-care testing (POCT) is another way of improving precision infection control, enabling the timely provision of diagnostic information at the point of patient care, enabling quicker initiation of targeted therapy (Didelot et al., 2017).

Table 5. Emerging Diagnostic Technologies in Precision Infection Control.

Technology	Principle	Clinical Application
PCR-based diagnostics	Detection of specific DNA/RNA sequences	Rapid pathogen and resistance gene identification
Multiplex molecular assays	Simultaneous detection of multiple targets	Detection of mixed infections
Whole-genome sequencing	Complete microbial genome analysis	Outbreak tracking and resistance surveillance
MALDI-TOF MS	Protein-based microbial identification	Rapid bacterial and fungal identification
Point-of-care testing	Bedside diagnostic analysis	Immediate clinical decision-making

4.2 Artificial Intelligence and Digital Healthcare

To enhance prediction, surveillance, and clinical decision-making, artificial intelligence (AI) and digital healthcare technologies are increasingly being incorporated into programs of infection prevention. Electronic health records, microbiological data, and hospital admission patterns can all be used to identify which patients are at high risk of developing HAIs, which can then be used in an AI-based model to analyze large volumes of data. There have been promising results concerning machine learning algorithms predicting outbreaks of infection, detecting unusual transmission patterns and helping with early intervention strategies. AI-driven analytics and electronic surveillance can be used to track infection patterns and antimicrobial resistance in healthcare settings, on an ongoing basis. Clinical decision support systems (CDSS) support healthcare professionals with evidence-based recommendations for antibiotic selection, dosage optimisation and length of treatment. These technologies have shown to help with antimicrobial stewardship and minimize unnecessary antibiotic use, but they will need to be high-quality, clinically proven, and integrated into clinical workflows to be effective (Bates et al., 2021)

4.3 Precision Infection Control

Precision infection control is a new approach to controlling infections, which looks beyond population-based strategies and into data-driven approaches at an individual level. In this manner, patient, pathogen genomic data, antimicrobial susceptibility data and epidemiological data are combined to create a tailored infection prevention and treatment (IPT). Risk stratification can be used to identify patients at risk and target them for more frequent monitoring, earlier diagnostic testing or prevention of disease. Personalized antimicrobial therapy requires the use of the right antibiotic(s) for the right pathogen, taking resistance mechanisms into consideration, as well as patient factors and the drug's properties. Biomarker-guided treatment strategies can help with antibiotic initiation and de-escalation and minimise unnecessary exposure to antibiotics, thereby decreasing the development of resistance. Precision surveillance integrates genomic epidemiology with real-time monitoring, and digital health systems to improve detection of transmission events and response to infection control (Murray et al., 2022).

4.4 Novel Therapeutic Approaches

The threat of developing multidrug-resistant pathogens has spurred the development of other ways of attacking microorganisms rather than using traditional antimicrobial agents. Bacteriophage therapy has received a lot of interest as they are able to target bacterial pathogens and not the beneficial microbiota. With the development of phage engineering, there is an increased potential for the use of phages in treating infections from resistant organisms. Another exciting strategy is the use of antimicrobial peptides (AMPs), as they are active against a wide range of microorganisms and can disrupt bacterial cell membranes. Pathogen-specific prevention and treatment with monoclonal antibodies is being explored against the pathogen virulence factors or pathogens toxins. Probiotics and fecal microbiota transplantation (FMT) represent therapeutic approaches aimed at restoring microbial balance and preventing conditions such as *Clostridioides difficile* infection. Finally, Nanotechnology-based antimicrobial delivery systems (such as nanoparticles and smart drug-delivery platforms) have the potential to demonstrate advantages such as an improved drug stability, targeted delivery, and controlled release. These new strategies can be used alongside current antibiotics and help inform future, precision-based, strategies for tackling resistant hospital infections (Mookherjee et al., 2020).

Table 6. Novel Therapeutic Strategies Against Multidrug-Resistant Hospital Pathogens.

Therapeutic Approach	Mechanism	Potential Application
Bacteriophage therapy	Specific bacterial lysis	MDR bacterial infections
Antimicrobial peptides	Membrane disruption and immune modulation	Resistant bacterial infections
Monoclonal antibodies	Pathogen or toxin neutralization	Targeted infection prevention
Microbiome-based therapy	Restoration of microbial balance	Prevention of dysbiosis-associated infections
Nanotechnology-based delivery	Targeted and controlled antimicrobial release	Enhanced therapeutic efficacy

5. CHALLENGES, RESEARCH GAPS, AND FUTURE PERSPECTIVES

5.1 Current Challenges

Although there are great strides in infection prevention, antimicrobial stewardship, and diagnostic technologies, controlling hospital-acquired infections (HAIs) in the antimicrobial resistance (AMR) era is still difficult. Established antimicrobial therapies are becoming less effective against ever emerging and spreading multidrug resistant (MDR) pathogens and treatment is becoming more difficult. Limited treatment options and adverse clinical outcomes are linked to resistant organisms like carbapenem-resistant Enterobacterales, multidrug-resistant *Acinetobacter baumannii* and resistant *Pseudomonas aeruginosa* (Antimicrobial Resistance Collaborators, 2022). The other big challenge is the lack of antibiotic development. Due to scientific, regulatory, and economic challenges, the discovery pipeline for new antibacterials has slowed significantly and many of the new compounds have been rejected due to their toxicity risks. Moreover, practices to prevent infection differ greatly between countries due to differences in healthcare infrastructure, availability of trained personnel, diagnostic capacity and financial resources. Countries with low- and middle-income levels have a higher burden of HAIs than developed nations because they may have limited access to improved technologies in infection control and surveillance, and lack adequate hospital infrastructure for infection control (Murray et al., 2022). The cost of HAIs is significant, with longer hospital stays, more tests and additional, costly antimicrobial treatment, and greater health care expenses. Inadequate laboratory capacity and time for pathogen identification also play a role in the inappropriate use of antibiotics and insufficient infection-control response.

Table 7. Major Challenges in Controlling Hospital-Acquired Infections.

Challenge	Impact on Healthcare
Rising antimicrobial resistance	Reduced effectiveness of available antibiotics

Limited antibiotic pipeline	Fewer treatment options for MDR infections
Global disparities in infection control	Unequal prevention and management strategies
Economic burden	Increased healthcare expenditure
Infrastructure limitations	Delayed diagnosis and poor surveillance

5.2 Research Gaps

Precision infection control has been shown to have great promise, but there are several research gaps that must be filled before it can be broadly implemented in the clinic. A significant drawback is the absence of uniform systems for incorporating genomic data, artificial intelligence (AI), microbiological data and clinical data into a normal infection control process. Establishing a set of accepted guidelines on a global scale is vital to ensure consistency in applying them in various healthcare settings. Development of reliable biomarkers for early detection and monitoring of treatment of infection is still one of the important research needs. Identify specific markers to differentiate bacterial infection from non-infectious inflammation could have the potential to decrease unnecessary antibiotic use and support antimicrobial stewardship. Likewise, a real-time surveillance system that integrates electronic health records, microbiological data, and epidemiology information also needs to be further validated before a broader adoption. AI-based models have demonstrated promise in predicting infections and identifying outbreaks, but there exists a dearth of models which have been externally validated and clinically tested in various healthcare settings. Further research is needed to enhance the transparency, accuracy, and clinical workflow integration of models. The personalized stewardship of antimicrobials also demands further research to explore the synergy between patient factors, pathogen characteristics and pharmacologic data for optimal selection of antimicrobials (Topol, 2019).

5.3 Future Perspectives

Precision medicine, advanced diagnostics, and digital technologies are likely to be key in supporting the future management of HAIs. Combining patient risk factors, pathogen genomics and environmental surveillance will allow for precision public health approaches, which will enable targeted interventions. Genomic surveillance will become an increasingly vital tool to understand transmission dynamics, detect novel resistance mechanisms and aid in early outbreak response. The new idea of smart hospitals, that involve automated surveillance systems, AI technology, robotics, and inter-connected healthcare devices could lead to better real-time tracking of infection hazards. Furthermore, digital epidemiology utilizes electronic health records, wearable technologies, and data analytics to provide early warnings of infection trends and proactive prevention strategies. Addressing AMR through a One Health framework that focuses on the interconnections between human, animal and environmental health will be critical. International cooperation, sharing of data, investment in antimicrobial research and bolstering of healthcare systems will be vital for sustainable control of HAIs globally (Robinson et al., 2016).

CONCLUSION

Hospital-acquired infections (HAIs) remain a significant problem in contemporary healthcare, especially within today's context of rising antimicrobial resistance (AMR). The persistent occurrence of MDR pathogens has rendered the management of infections increasingly complex and led to increased treatment failure rates, morbidity and mortality rates and economic costs due to healthcare-associated infections. To effectively prevent HAI, a multi-faceted prevention strategy that incorporates rigorous infection prevention measures, antimicrobial stewardship programs, and ongoing surveillance systems is needed. The standard infection control precautions such as hand hygiene, environmental cleaning, isolation and training of health care workers are all still vital in preventing HAIs. But resistant pathogens are complex and advanced strategies are needed that go beyond what can be achieved with a traditional approach. An important part of antimicrobial stewardship is rational use of antimicrobials, minimization of unnecessary antimicrobial exposure and ensuring the efficacy of existing antimicrobials. With the advent of precision infection control, new opportunities have arisen for enhancing the safety of patients and utilizing rapid diagnostics, genomic surveillance, and the use of AI-based prediction models and personalized antimicrobial treatment. These technologies can help to identify infections at an early stage, to correctly identify the pathogen, and to undertake targeted measures. While the results are promising, several factors, such as standardized protocols, clinical validation, better data quality, and access to high-tech healthcare solutions, must be addressed for successful implementation. Moving forward, infection control strategies should incorporate precision public health, digital surveillance systems, smart

hospital systems, and One Health frameworks that link human, animal and environmental health. Global collaboration and improvement of healthcare infrastructure, as well as investment in innovative antimicrobial and diagnostic technologies, will play a crucial role in curbing the impact of HAIs and tackling the emerging challenge of AMR. The transition to data-driven and personalized infection control can help make healthcare environments safer and help to enhance long-term clinical outcomes.

Conflict of Interest

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

Author contributions

The initial draft of the manuscript was prepared by the first author, who led the background synthesis, methodology layout, and primary textual development. The corresponding author oversaw the entire drafting process, providing critical structural guidance, technical validation, and project oversight. Every co-author actively participated throughout the preparation phases: identifying relevant data sources, extracting and validating evidence, formulating structured comparison tables, and performing thorough line-by-line editorial revisions. Following a rigorous internal review to ensure academic integrity and methodological rigor, all listed authors gave their unanimous approval for the manuscript to be submitted for journal publication.

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