ANTIMICROBIAL RESISTANCE IN HEALTHCARE FACILITIES: CHALLENGES AND STRATEGIES FOR MANAGEMENT

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Abstract: Antimicrobial resistance (AMR) presents a serious risk to public health worldwide, requiring effective management strategies in healthcare facilities. Healthcare-associated infections, including those caused by multidrug-resistant organisms (MDROs), are major drivers of AMR in healthcare facilities, and may be significantly influenced by hospital transfers within or between healthcare units and regions. Challenges in managing AMR in healthcare facilities include inappropriate and suboptimal antibiotic prescription practices, the evolution of multidrug resistant organisms, AMR healthcare-associated infections, poor compliance with infection prevention and control measures, and non-implementation of antimicrobial stewardship programs. AMR can be successfully managed in healthcare facilities by implementing antimicrobial stewardship programs, adherence to infection prevention and control measures, surveillance and monitoring of AMR trends, and innovations in diagnostics and therapeutics for AMR.

Keywords: Antimicrobial resistance (AMR), Multidrug-resistant organisms (MDROs), Antimicrobial stewardship programs, Infection prevention and control (IPC), Healthcare-associated infections (HAIs).

Introduction

Antimicrobial resistance (AMR), widely referred to as the "Silent Pandemic", is a growing global health issue with the potential to undermine modern medicine (Founou *et al*., 2021). AMR occurs when microorganisms such as bacteria, fungi, parasites, and viruses evolve to the point where they eventually develop resistance to antimicrobial medications like antibiotics, which are used to treat such conditions (WHO, 2021). Due to the sharp increase in the number of AMR infections and the dearth of new antimicrobial drugs being developed to address this problem, AMR has become one of the biggest worldwide challenges of the twenty-first century (Prestinaci *et al*., 2015). According to global estimates, AMR was directly responsible for 1.27 million global deaths in 2019 and contributed to 4.95 million deaths and is forecast to increase to approximately 10 million deaths per year by 2050, if appropriate measures are not taken (Murray *et al*., 2022). The effects of overuse or careless use of antibiotics in various settings, particularly in healthcare settings coupled with agricultural usage, animal healthcare, and the food system, may be one of the primary drivers of the current problem (Tang *et al*., 2023).

The emergence of antibiotic-resistant organisms, particularly in hospitals and other healthcare facilities, has raised serious concerns in public health. Several antibiotic-resistant pathogens including Methicillin-resistant *Staphylococcus aureus* (MRSA), *Enterococcus* resistant to vancomycin, extended-spectrum β-lactamase-producing Gram-negative bacilli, *Klebsiella* species resistant to carbapenem and other Enterobacteriaceae, Multidrug-resistant *Pseudomonas aeruginosa,* and other AMR organisms, have been identified as causes of serious infections among patients in hospitals in the last two decades (Raman *et al*., 2018; Jernigan *et al*., 2020; Sakkas *et al*., 2019). In patients with these drug-resistant infections, the bacteria can be transmitted through direct personal contact, medical equipment, and contaminated environments (Raman *et al*., 2018). The high colonization prevalence of antimicrobial resistance in healthcare facilities can be attributed to the proximity of vulnerable individuals who may be suffering from drug-resistant infections, require indwelling or invasive devices, or require prolonged antibiotic use due to persistent or recurrent infections (Rodriguez-Villodres *et al*., 2021). These vulnerable individuals also have frequent contact with healthcare, which offers opportunities for onward transmission and acquisition of MDR organisms, within and between healthcare facilities.

Concerns over the future of antimicrobial therapy have grown considering the rise in drug-resistant microbe prevalence and the slow pace in the discovery of new effective antibiotics in recent years (Podolsky, 2018). Although research and development of new antimicrobial drugs are considered the most direct approach to combat multidrug-resistant organisms, financial and technical challenges have been major hindrances, as the process requires significant investment with little financial incentives for pharmaceutical companies (WHO, 2021). Evidence suggests a strong relationship between antibiotic usage levels and the prevalence of antibiotic resistance in individuals and communities (Holmes *et al*., 2016). Therefore, antibiotic use alone is not a long-term approach to stop the present AMR epidemic.

A different and practical approach to lowering the prevalence of antimicrobial resistance is infection prevention and control (IPC). This approach consists of two kinds of interventions: horizontal and vertical. While horizontal interventions seek to reduce the transmission of many pathogens concurrently by introducing standardized practices, vertical solutions target a reduction in the transmission of certain infections with active screening programs followed by decontamination (Wong *et al*., 2022). However, there are significant differences in the IPC practices used in hospitals in treating MDR bacterial infections both within and between countries. There is no consensus on the optimal IPC measures or combinations of various measures to reduce the transmission of MDR organisms in hospitalized patients. Previous guidelines, such as those from the Health Care Infection Control Practices Advisory Committee (HICPAC)/CDC, provided only generic guidance for controlling MDR organisms (Sturm *et al*., 2021). Effective antimicrobial stewardship programs can enhance patient care and be financially self-sufficient (Coque *et al*., 2023). In addition to minimizing inappropriate use, antimicrobial stewardship entails optimizing the choice, dosage, delivery method, and length of therapy to maximize clinical cure or infection prevention while minimizing unintended consequences like drug resistance emergence, adverse drug events, and cost (WHO, 2021; Wong *et al*., 2022). This review aims at investigating the effectiveness of current antimicrobial stewardship programs and infection control measures in addressing the challenges posed by MDR organisms in healthcare facilities, and novel strategies that can be implemented to enhance AMR management.

Epidemiology of Antimicrobial Resistance in Healthcare Facilities

Healthcare-associated infections, including those caused by MDROs, are a major driver of AMR in healthcare facilities. AMR may be significantly influenced by hospital transfers within or between healthcare regions, typically when patients move from a rural or regional hospital to a university medical center or the other way around (Glasner *et al*., 2022). Although the impact of patient mobility within a hospital on the transmission of pathogens has not been fully understood, it has been reported that intra-hospital patient movements may play a similar function to movement of patients between hospitals in the transmission of MDROs within a hospital (Tahir *et al*., 2021). The difficulty in understanding this could be because these studies were restricted to intensive care units, or to some particular hospital units.

Numerous studies have reported that about 90% of HAIs are caused by bacteria found in intensive care units where patient severity, widespread use of broad-spectrum antibiotics, and invasive procedures encourage the formation and transmission of AMR (Vilches *et al*., 2019). Environmental contamination, contact between patients and healthcare workers as well as patient-to-patient contact can spread these infections across hospital populations (WHO, 2021). Surfaces, medical equipment, and healthcare environments can serve as reservoirs for MDROs, facilitating their transmission between patients. High-touch surfaces, such as doorknobs, bed rails, and medical devices, can become contaminated with resistant organisms and contribute to the spread of infections (Raman *et al*., 2018). Patients with active infections or colonization with resistant organisms can shed bacteria into the environment, where they can survive for extended periods and potentially infect susceptible individuals (Jernigan *et al*., 2020). Healthcare workers can inadvertently transmit MDROs between patients through contaminated hands, clothing, or medical equipment. Inadequate infection control practices, suboptimal hand hygiene, improper sterilization techniques, lapses in isolation protocols, and deficiencies in environmental cleaning contribute to the persistence and dissemination of these MDROs in healthcare facilities (Aijaz *et al*., 2023). Infections caused by these MDROs can lead to prolonged hospital stays, increased morbidity and death rates, and decreased quality of life for patients. The presence of AMR further complicates the treatment of these infections, leading to increased healthcare costs and higher rates of treatment failure (Tahir *et al*., 2021).

Challenges in Managing Antimicrobial Resistance in Healthcare Facilities

Inappropriate and Suboptimal Antibiotic Prescription Practices

Injudicious prescription and misuse of antimicrobials are considered major drivers of AMR in healthcare facilities. According to reports from WHO, less than 40% and 30% of patients in both publicly and privately owned facilities, respectively, receive treatment in accordance with WHO recommendations (WHO, 2021). Prescribers frequently tackle suspected bacterial infections, both gram-positive and gram-negative, with wide spectrum antibiotics (Alzahrani *et al*., 2018). In several circumstances, antibiotics are administered for diseases that do not require antibiotic treatment. Although this is a global concern, the inappropriate use of antibiotics is greater in low- and middle-income countries (LMICs), with studies showing the wide range in the determinants of antibiotic prescription practices in healthcare facilities in LMICs (Kpokiri *et al*., 2020). These determinants include a lack of updated policies and treatment guidelines, quality of antimicrobials prescribed, and poor knowledge of the antibiotic prescription and problems posed by AMR. Antibiotic-resistant bacteria, including MRSA, are more widespread in low- and middle-income countries (LMICs) due to suboptimal antibiotic prescribing methods (Andreatos *et al*., 2018). High numbers of antibiotic prescriptions are a common feature of LMIC prescribing, albeit there may be some correlation between these higher levels and an increased burden of infectious illnesses (Anong and Akoachere, 2018). Prescription practices in LMICs are also marked by a high empirical use of broad-spectrum antibiotics, a lack of treatment recommendations or inadequate adherence to them, and a limited use of diagnostic tests before prescription of antibiotics (Alzahrani *et al*., 2018; Kpokiri *et al*., 2020). Since the lines separating the public, commercial, nonprofit, and mission sectors are so thin, antibiotics can be obtained outside legal frameworks and come in various quality levels. With the availability of over-the-counter antibiotics, patients will have the opportunity to self-medicate which will be impacted by circumstances, including time and finances (Merrett *et al*., 2016).

Evolution of MDROs

The widespread use of antibiotics in healthcare facilities influences bacterial populations selectively, promoting the survival and spread of resistant strains. Over time, repeated exposure to antibiotics leads to the emergence of resistance mechanisms through spontaneous mutations or acquisition of resistance genes from other bacteria (Lerminiaux and Cameron, 2019). Through horizontal gene transfer, microbial species can acquire new genetic material from outside their clonal lineage, enabling diversification of genomes, and contributing to infections and outbreaks through the transfer of resistant pathogenic genes (Lerminiaux and Cameron, 2019).

Considering the numerous unique aspects of clinical environments, it has been difficult to ascertain or speculate the effects of horizontal transfer in clinical settings, and the impacts of horizontal gene transfer on disease frequency. The main agents of horizontal gene transfer through conjugation, transduction, and natural transformation are plasmids, bacteriophages, and extracellular DNA respectively (Andersson and Hughes, 2017). Although the sources, processes, and frequency of antibiotic-resistance gene transfer between clinical reservoirs are poorly understood, there are several examples where the same antibiotic-resistant gene has been found concurrently in patients and on hospital surfaces. Recently, a study combination of hospital epidemiological data with mathematical modelling was used to predict the probability of $bla_{\text{OXA-48}}$ plasmid transfer between *Escherichia coli* and *Klebsiella pneumoniae* within hosts (Haverkate *et al*. 2015). Clinical resistance in Gram-positive bacteria, such *Staphylococcus aureus*, is also impacted by plasmid transfer. Conventional antibiotics are not always effective in treating infections caused by methicillin-resistant *Staphylococcus aureus* (MRSA), a common source of hospital-acquired infections (Tsouklidis *et al*., 2020). When treating MRSA and other Gram-positive bacteria that are resistant to antibiotics, vancomycin is usually the drug of last resort. However, through the horizontal transfer of a plasmid from *Enterococcus faecalis*, vancomycin-resistant *Staphylococcus aureus* (VRSA) emerged from MRSA (Li *et al*., 2022). This incident offers a crucial illustration of how horizontal gene trasnfer concentrates resistance genes in genomes, which aids the formation of so-called "superbugs" resistant to all available antibiotics (Afzaal *et al*., 2020).

Transduction may play a major role in the establishment and persistence of antibiotic resistance in clinically relevant *Staphylococcus aureus*, as bacteriophage-mediated transfer of antibiotic resistance can happen in laboratory settings. A study by Stanczak-Mrozek *et al*. (2015) discovered that bacteriophages derived from MRSA infections acquired in hospitals could easily transduce antibiotic-resistant genes to susceptible strains. Similar to this, a study by Mašlaňová *et al*. (2016) showed the possibility of hospital isolates of *Staphylococcus aureus* to transduce tetracycline and penicillin resistance genes.

AMR Healthcare-Associated Infections (HAIs)

HAIs and AMR are two of the largest threats to global public health (Jain *et al*., 2021). HAIs, also known as nosocomial infections, are infections contracted by patients while receiving medical treatment in healthcare facilities (Joshi *et al*., 2019). These infections can manifest in various forms, including surgical site infections, urinary tract infections, bloodstream infections, and pneumonia (Jain *et al*., 2021). Approximately two million patients in the USA, contract AMR HAIs annually, which leads to 23,000 fatalities (Argirova and Zlatareva, 2022). The number of fatalities linked to HAIs was approximated to be 5,000 every year in the United Kingdom. Every year, about four million people contract HAIs in every Member State of the European Union, and roughly 37,000 of these infections directly caused mortality (Russo *et al*., 2021). Most of these deaths were caused by the most prevalent microorganisms resistant to multiple drugs.

While hospitals are the primary setting where HAIs occur, they can also emerge in nursing homes, outpatient clinics, and other healthcare environments. HAIs have a major impact on morbidity, mortality, and the use of healthcare resources, making them a critical patient safety problem (Joshi *et al*., 2019). MDROs that can result in severe clinical syndromes are known to circulate across hospitals. HAIs with MDR bacteria can be fatal, need expensive and complex treatment, and are difficult to treat (Liu *et al*., 2020). These infections strain health systems, result in significantly increased morbidity and mortality, and increased direct and indirect expenditures. The study by Liu *et al.* (2020) discovered that between 2013 and 2015, the total expenditure and medicines expenditure of the AMR HAI patients almost doubled, and the average length of hospital stay also increased steadily. Since resistant microorganisms are frequently the cause of HAIs and because the presence of HAIs can raise the likelihood of generating resistant strains, the problem of AMR and HAIs are intimately related and are difficult to manage (Irek *et al*., 2018).

Poor Compliance with Infection Prevention Control (IPC) Measures

Although about 55-70% of HAIs may be preventable through standard precautions including hand hygiene, use of gloves, gowns, eye protection, prophylaxis after exposure to bloodborne pathogens, and safe disposal of sharp instruments, lack of knowledge of guidelines for IPC measures during routine patient treatment and the possible dangers of the transmission of MDROs, hamper compliance to IPC measures (Umscheid *et al*., 2011; Alhumaid *et al*., 2021). Insufficient awareness on the suitability, effectiveness, and application of IPC measures contributes to low compliance (Russell *et al*., 2018). Several studies have observed that healthcare workers' adherence to IPC practices such as hand washing and use of PPE varies greatly, and that this variation is probably due to individual differences in behavior and awareness of infection risk (Alhumaid *et al*., 2021; Amsalu and Kassaye, 2022).

A cross-sectional study by Lien *et al.* (2018) reported a disparity in the knowledge of IPC measures between staff in medical facilities; cleaners had lower knowledge score than physicians and nurses/midwives. Even though cleaning is one of the most effective interventions for reducing HAIs in hospitals, and cleaning personnels might spread MDROs within hospitals through their work and themselves, the contribution of cleaners/cleaning to infection control is typically underestimated. Good IPC practice is more complicated than knowledge or experience alone. For instance, despite established protocols for preventing HAIs, healthcare workers have been seen to exhibit inadequate and inconsistent adherence to hand hygiene measures (Alhumaid *et al*., 2021). The cross-sectional study by Lien *et al.* (2018) reported that healthcare workers cited a heavy workload and emergencies as the primary causes of their non-compliance. Patients in emergency situations need to be examined quickly. However, if hospital staff disregard conventional operating protocols for hygiene, these patients may present with more critical health conditions, rendering them more susceptible to AMR HAIs (Lien *et al*., 2018).

Non-implementation of Antimicrobial Stewardship (AMS) Programs

The World Health Organization created a global action plan in 2015 to address antimicrobial resistance, by lowering the incidence of infectious diseases, raising awareness of AMR, and encouraging the prudent use of antibiotics (WHO

EMRO, 2015). The agency identified AMS program as one of the key strategies under the global action plan, particularly in light of the decreasing supply of new antimicrobials to combat MDROs. AMS, as a strategy, may be seen as a concerted series of steps to encourage the responsible use of antibiotics, with the ultimate objective being to maximize clinical results while avoiding the unfavorable effects, such as resistance development and unpleasant drug responses (Dyar *et al*., 2017; Kakkar *et al*., 2020). Although AMS programs are crucially needed to curb the effects of AMR, the components necessary for their successful implementation are hardly in place, or not specifically backed by national or institutional policies especially in LMICs (Gebretekle *et al*., 2018).

The key factors preventing the successful implementation of AMS in healthcare facilities, especially in LMICs include lack of a clear political commitment, easy availability of antimicrobials, inability to totally adhere to IPC measures, insufficient funding, congested healthcare systems, loose legal and regulatory frameworks, uneven access to diagnostics, lack of electronic health record systems, low knowledge and awareness particularly in light of the existence of multiple medical systems, problems obtaining quality-assured medications, internal pharmacies, and a shortage of trained medical personnels (Kakkar *et al*., 2020). Furthermore, a wide range of individuals with varying degrees of training, including healthcare professionals like nurses, chemists, dentists, midwives, practitioners of alternative medicine (including herbalists, area chemists, faith healers and quacks), frequently prescribe antibiotics in many LMICs (Barker *et al*., 2017; Nair *et al*., 2019). Due to a lack of knowledge about the processes involved in developing guidelines and the scarcity of relevant data, these prescribers outlined above frequently do not have access to context-specific guidelines (Kakkar *et al*., 2020). Even in cases where guidelines are available, their adoption may fall short because of a lack of local adaptations or insufficient dissemination.

Strategies for Antimicrobial Resistance Management in Healthcare Facilities

Antimicrobial Stewardship Programs: Implementation and Effectiveness

Antimicrobial stewardship programs (ASPs) can optimize the treatment of infections and reduce AMR and other adverse events associated with antibiotic use (Coque *et al*., 2023). The least harm to the patient and other patients can be caused by taking the appropriate antibiotic for the right indication (diagnosis), at the right time, with the proper dose, route, and length of therapy (Majumder *et al*., 2020). Strict adherence to these guidelines guarantees that medical practitioners will only recommend antibiotics for bacterial infections that are not self-limiting. For a successful implementation of AMS, the strategy of prospective audit and feedback recommended by the Infectious Disease Society of America serves as a core component (Kakkar *et al*., 2020). This approach involves a multidisciplinary team, typically including a microbiologist, clinical chemists, and specialists in infectious diseases. Although these positions are typically filled by certain healthcare experts, anyone with the necessary training, drive, and experience can be trained to do AMS tasks successfully.

Education sessions can also serve as a fundamental strategy for implementing AMS in healthcare settings, effectively influencing prescriber behavior, and promoting adherence to stewardship principles (Kakkar *et al*., 2020). These sessions, which can be formal or informal, aim to inform and engage medical professionals, including doctors, in stewardship activities. Continuing medical education presentations, group teaching programs, and mobile/email alerts and notices could be forms of formal education sessions. On the other hand, non-formal education involves spontaneous bedside instructions by members of the stewardship team during patient care rounds. The content of these sessions varies, covering basic AMS guidelines, sensible antibiotic prescription for particular reasons or clinical circumstances, and supportive measures such as interpreting culture and susceptibility reports and utilizing local guidelines (Luther *et al*., 2018). The success of AMS interventions often hinges on adequate and timely education sessions targeting healthcare professionals. These sessions may play a crucial role in presenting specific data on antimicrobial use, highlighting improvements, or worsening prescription trends, and motivating improved prescribing practices (Gebretekle *et al*., 2018). However, to have a major impact, instructional sessions must be combined with complementary interventions and outcome evaluation as they have limited effect by themselves.

Infection Prevention and Control (IPC) Measures

Among the three pillars of an integrated strategy for bolstering health systems, AMS is the major one, with the other two being IPC and patient safety (Majumder *et al*., 2020). The success of AMS is largely determined by IPC inclusiveness because an IPC cannot be carried out separately. Healthcare epidemiologists and infection prevention experts are essential in managing AMR in healthcare facilities, to detect and promptly handle outbreaks. These teams, often led by epidemiologists, monitor pathogen prevalence and environmental isolates, crucial for identifying sources and implementing precautions to prevent pathogen spread (Morrison and Zembower, 2020). For instance, in the case of a *Pseudomonas aeruginosa* outbreak in a healthcare facility, control strategies can be used to prevent the spread of the infection after gathering case data, possible causes like the use of tainted solutions, poor instrument cleaning, reprocessing, and sterilization, and poor instrument drying, rinsing, and storage, can then be investigated (Morrison and Zembower, 2020). Following that, they might put in place surveillance measures for all patients who have recently had an endoscopy, including continuous scope cultures or prospective electronic monitoring for bacteremia. Throughout and after the epidemic, they would collaborate closely with endoscopy staff to manage this and stop further recurrences.

A study by Umscheid *et al*. (2011) estimated that about 55-70% of HAIs including the ones caused by MDROs, may be preventable through standard precautions including hand hygiene and the use of PPE. Van *et al.* (2017) evaluated how hand hygiene interventions may prevent infections by both drug-resistant and drug-sensitive bacteria, by creating a deterministic compartmental model. The model demonstrated how strains spread in both community and hospital environments. In the former, it was thought that the hands of healthcare workers were the source of transmission, and that contamination could be eliminated by practicing hand cleanliness. Furthermore, based on the existence and lack of pharmacological pressure in the two environments, they hypothesized that resistant strains are better suited to the hospital setting and sensitive strains to the community setting. They discovered that the better-adapted strain is significantly impacted by hand hygiene interventions that target one of the habitats.

Carriers of MDROs may serve as conduits for the transmission of these resistant microorganisms when patients are admitted to or moved between medical facilities. Therefore, core IPC measures should be implemented and maintained for all patients admitted into healthcare facilities throughout their stay (Magiorakos *et al*., 2017). When a patient's microbiological result indicates the presence of MDROs, either from active screening or a clinical culture, the microbiology laboratory should notify the appropriate staff as soon as possible. The positive result should also be clearly marked in the patient's record, and when the patient is transferred between units or healthcare facilities, the patient's status should be promptly communicated.

Surveillance and Monitoring of AMR Trends

Surveillance and monitoring of AMR involve the systematic collection, analysis, and interpretation of data on antimicrobial susceptibility patterns among pathogens circulating within healthcare facilities, which allows for the early detection of emerging resistance trends and outbreaks of resistant pathogens, enabling prompt intervention and containment measures (Canton *et al*., 2023). To mitigate AMR, extensive monitoring programs that evaluate changes in resistance to antibacterial drugs over time are essential. Surveillance is a fundamental component of the global action plan on AMR developed by the World Health Organization (Diallo *et al*., 2020). Through the identification of antibacterial susceptibility patterns, resistance trends, and emerging resistance threats, surveillance program can aid in the development of AMS program and evaluate their efficacy, inform treatment decisions, guide efforts to develop new treatment options, and direct national and local policies and clinical guidelines (Canton *et al*., 2023). To achieve these objectives, surveillance programs need to include the pertinent pathogens and antibacterial agents, and data needs to be gathered and processed in real time using a standardized approach. The burden of AMR has been repeatedly demonstrated to be reduced by the successful implementation of AMS programs, particularly in developed nations with strong healthcare systems and comprehensive surveillance data providing evidence-based support (Majumder *et al*., 2020). The implementation of AMS projects in LMICs is often hindered by structural and other issues, and the lack of data regarding the effectiveness of surveillance-based AMS initiatives in environments with limited resources (Kpokiri *et al*., 2020).

Numerous surveillance programs are in existence at the moment, with differing characteristics regarding their geographic coverage (local, national, regional, or worldwide), scope (pathogens, antibacterial agents, and particular infection sites), and data kind and quality (Diallo *et al*., 2020). Programs for AMR surveillance are typically supported by the pharmaceutical sector or public health agencies. The Global Antimicrobial Resistance and Use Surveillance System (GLASS) of the World Health Organization (WHO), the European Antimicrobial Resistance Surveillance Network (EARS-Net), the Africa Centers for Disease Control and Prevention Antimicrobial Resistance Surveillance Network, the National Antimicrobial Resistance Monitoring System for Enteric Bacteria (NARMS) in the United States, the English Surveillance Program for Antimicrobial Utilization and Resistance (ESPAUR), and the Japan Nosocomial Infections Surveillance (JANIS) are a few notable public health surveillance initiatives. Although these programs vary in terms of their geographic coverage, scope, and data collection methods, they play important roles in the management of AMR in healthcare facilities by providing essential data and insights for guiding AMS efforts, informing clinical decision-making, and supporting public health interventions (Canton *et al*., 2023).

Innovations in Diagnostics and Therapeutics for AMR

For infectious diseases to be treated as effectively as possible, early pathogen detection is essential. Despite significant advancements in medical technology, turnaround times for microbial pathogen identification and characterization can reach several days (Cansizoglu *et al*., 2019). Because of this, doctors are pressured to begin empirical antibiotic treatments—which are usually broad-spectrum—before a diagnosis is made. This approach could have negative effects on the patient's health as well as exacerbate the ongoing AMR problem (Kaprou *et al*., 2021). As a result, there is an immediate need for quick, extremely sensitive, reasonably priced, and economically viable AMR diagnostic detection devices. To monitor public health and direct medical treatment, diagnostic tests that can differentiate bacterial infections from other illnesses and identify the presence of antibiotic resistance are crucial (O'Neil, 2015). This could prevent the overuse or needless administration of antibiotics.

Rapid diagnostic tests related to infectious diseases are considered critical tools for AMS programs because of their role in reducing mortality, lessening hospital stays, decreasing antibiotic use, and reducing healthcare costs (Kaprou *et al*., 2021). Although new time-saving technologies have been introduced to diagnose AMR, conventional technologies such as culture-based and molecular-based methods are still in use. The use of rapid diagnostic methods such as a rapid syndromic multiplex PCR for the identification of particular respiratory viral infections can assist to prevent unnecessary testing, cut down on the use of needless antibiotics, and assist in the selection of suitable medications, such as antiviral medicines (Brigadoi *et al*., 2022). To achieve the best treatment results, diagnostic tests that can concurrently distinguish between bacterial, viral, and other microbial causes should be accessible when patients with respiratory tract infections or other infections present at any healthcare facility to reduce the needless use of antibiotics and ensure the early delivery of antiviral medication (Bouzid *et al*., 2021). A recent study by Guillotin *et al*. (2022) suggested that the use of needless broad-spectrum antibiotic therapy may be decreased with the use of a quick syndromic multiplex PCR to find pathogens and resistance genes in lower respiratory tract specimens, all without raising the risk of treatment failure.

Conclusion

Although there have been intensive efforts to combat AMR, the management of AMR in healthcare facilities remain a complex challenge. Efforts to implement AMS programs and IPC measures in healthcare facilities have met significant resistance due to the continuous rise of MDROs, which have posed significant threats to patient safety and public health. Current strategies have focused on optimizing antibiotic use, enhancing surveillance and monitoring of AMR trends, and improving diagnostics and therapeutics. However, several gaps and challenges persist, including inappropriate antibiotic prescription practices, the evolution of MDROs, compliance with IPC measures, and the need for innovative diagnostic tools.

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