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Addressing Antimicrobial Resistance: Strategies, Innovations, System Integration, Challenges and Future Directions

Jawaher Mohammad Abdullah Humadi[1], Tanweer Abudo Sherwani[1], Badriah Ahmed Awagi Klibi[1], Hashem Ahmed Madkhali[1], Saad Mohammed Altuwalah[2], Adel Shabib Alotaibi[2], Amal Sager Othman Hakami[3], Shabbab Mohammed Alalyani[4], Siraj Fahad Mohammed Hakami[5], Hani Ghazi Alahmadi[6]*, Abdullah Abdulrahman Alkuwaykibi[6], Fatimah Ahmed Alsaleh[6], Bushra Sulaiman Faleh Albaiji[7], Fatima Abd Almalik Aljuraidan[8], Qidan Ayidh Qidan Albaqami[9]

[1]General Directorate of Health Affairs Jazan, Al Rawdah, Jazan-82723, Saudi Arabia
[2]Riyadh Second Health Cluster, Post Box-3881, Riyadh-13255 - 6729, Saudi Arabia
[3]Primary Health Care Center, Alasamilh, As Suways, Jazan 82617, Saudi Arabia
[4]Ahad Rafidah General Hospital, Alwurud, Ahad Rafidah 62242, Saudi Arabia
[5]Primary Health Care Center- Madhya, Jizan 82714, Saudi Arabia
[6]*Madinah Health Cluster, Saeed bin Alaas Street, Madinah-42351, Saudi Arabia
[7]Eastern Health Cluster, Othman Ibn Affan Street, Al Muraikabat, Dammam 32253, Kingdom of Saudi Arabia
[8]Al-Ahsa Health Cluster, Ministry of Health, Rashdiah Street, PO. Box 12944, Al-Ahsa- 31982, Kingdom of Saudi Arabia
[9]Directorate of Health Affairs Taif, 7238, Qurwa, Taif 26521, Kingdom of Saudi Arabia

***Corresponding author:** Hani Ghazi Alahmadi
E-mail: hani-909@hotmail.com(Hani Ghazi Alahmadi)

Abstract
With the World Health Organization (WHO) identifying AMR as a pivotal concern, collaborative efforts among healthcare stakeholders are imperative to mitigate its multifaceted drivers. Pharmacists, occupying a central position within the healthcare framework, play a pivotal role in antimicrobial stewardship programs (ASPs), ensuring the judicious use of antimicrobial drugs. Through proactive audits, medication reviews, and adherence to evidence-based guidelines, pharmacists contribute significantly to curbing the rise and spread of antimicrobial resistance. Moreover, they serve as educators, imparting crucial insights to patients on the prudent utilization of antibiotics and the importance of treatment adherence. By emphasizing the perils of antibiotic resistance and advocating for responsible antibiotic usage, pharmacists contribute to reducing unnecessary antibiotic consumption and mitigating the emergence of resistant strains. In addition to their roles in antimicrobial stewardship and patient education, pharmacists actively engage in infection prevention and control measures within healthcare settings. Collaborating closely with infection control teams, pharmacists promote rigorous hand hygiene practices, advocate for adherence to infection control guidelines, and monitor antimicrobial utilization patterns to identify areas for improvement. Furthermore, pharmacists play a pivotal role in advocating for policies and initiatives targeting AMR across various levels, including local, national, and international spheres. Their involvement in public health campaigns, legislative actions, and research endeavors underscores their commitment to mitigating AMR and safeguarding the efficacy of antimicrobial agents. Technological innovations further empower pharmacists in their efforts to combat AMR. From electronic health records (EHR) to artificial intelligence (AI) and machine learning (ML) algorithms, pharmacists leverage cutting-edge technologies to monitor antimicrobial consumption accurately, enhance adherence to clinical guidelines, and streamline communication across healthcare teams. Despite facing challenges such as limited authority and resource constraints, pharmacists' contributions in mitigating AMR remain indispensable. By strengthening policy frameworks, fostering interdisciplinary collaboration, and leveraging technological innovations, pharmacists can continue to lead efforts in combatting AMR and preserving the efficacy of antimicrobial agents for future generations.

Keywords: Antimicrobial Resistance, Pharmacists, Nursing, Antimicrobial Stewardship, Innovations, Patient Educations

1. Introduction
Antimicrobial resistance (AMR) constitutes a major global health threat, undermining the effectiveness of antibiotics, which are essential for combating bacterial infections. The World Health Organization (WHO) has identified AMR as a pivotal concern, jeopardizing the successful prevention and treatment of a growing spectrum of infections across bacterial, parasitic, viral, and fungal pathogens (1). AMR emerges as a result of microorganisms, such as bacteria, fungi, viruses, and parasites, undergoing changes that diminish the effectiveness of medications intended to treat the infections they provoke. Key contributors to the escalation of AMR encompass the excessive prescription of antimicrobials, insufficient patient adherence to treatment protocols, inappropriate

utilization of antibiotics within agriculture, and subpar infection control measures. The repercussions are severe and far-reaching, spanning prolonged illnesses, heightened healthcare expenses, elevated mortality rates, and a mounting global burden of treatment inadequacy (2). AMR presents a significant public health challenge by undermining the efficacy of antimicrobial agents, thereby restricting treatment modalities for infectious diseases.

As microorganisms evolve resistance mechanisms, the effectiveness of commonly utilized antibiotics, antifungals, antivirals, and antiparasitic drugs diminishes, resulting in prolonged illnesses, escalated healthcare expenditures, and heightened mortality rates. The ramifications of AMR transcend individual patient outcomes to burden healthcare systems and economies on a global scale. Immediate and concerted efforts are imperative to mitigate the multifaceted drivers of AMR, encompassing the inappropriate utilization of antimicrobials in both human and veterinary medicine, alongside insufficient infection prevention and control strategies (3). Efforts aimed at tackling AMR necessitate collaborative endeavors among healthcare practitioners, policymakers, researchers, and the general populace to enforce judicious antimicrobial stewardship measures, advocate for rational pharmaceutical consumption, and foster innovation in treatment modalities. The absence of a comprehensive approach to addressing AMR not only undermines the advancements achieved in contemporary medicine but also poses a significant challenge to the effective management of infectious ailments in forthcoming times (4).

1.1 Evolving Role of Pharmacists:

Pharmacists occupy a central role in combating AMR owing to their distinctive position within the healthcare framework. Traditionally acknowledged as authorities in medication, pharmacists have broadened their professional purview to encompass multifaceted responsibilities, spanning medication oversight, patient instruction, and advocacy for public health. In the context of AMR, pharmacists emerge as indispensable constituents of interdisciplinary healthcare cohorts, leveraging their specialized knowledge to enhance the utilization of antimicrobials and advocate for prudent prescription practices (5). Pharmacists contribute significantly to several critical aspects related to mitigating AMR **Error! Reference source not found.**.

Antimicrobial Stewardship:

Pharmacists are key players in antimicrobial stewardship programs (ASPs), working closely with other healthcare providers to ensure the appropriate use of antimicrobial drugs. They employ strategies like limiting certain antimicrobials on formularies, requiring preauthorization for their use, and conducting proactive audits with feedback loops. Through comprehensive medication reviews and adherence to evidence-based guidelines, pharmacists help curb the rise and spread of antimicrobial resistance (6).

Patient Education and Counseling:

In inpatient education and counseling, pharmacists assume a pivotal role in instructing patients on the correct utilization of antibiotics and the significance of adhering to the prescribed treatment regimen. They offer insights into the perils of antibiotic resistance, stressing the imperative nature of treatment adherence and the mitigation of unnecessary antibiotic consumption. Additionally, pharmacists educate patients on the optimal handling of prevalent infections, encompassing non-pharmacological interventions and strategies for symptom management (7).

Infection Prevention and Control:

Pharmacists play a crucial role in bolstering infection prevention and control measures within healthcare settings. Their contributions encompass the promotion of hand hygiene, the establishment of rigorous environmental cleaning protocols, and the active advocacy for adherence to infection control guidelines. Collaborating closely with infection control teams, pharmacists engage in the systematic monitoring of antimicrobial utilization patterns, pinpointing areas ripe for enhancement, and deploying tailored interventions aimed at mitigating the prevalence of healthcare-associated infections and the emergence of antimicrobial-resistant strains (8).

Public Health Advocacy:

Pharmacists actively participate in advocating for policies and initiatives targeting AMR across local, national, and international spheres. Their involvement spans public health campaigns aimed at promoting responsible antibiotic usage, antimicrobial stewardship, and infection control. Moreover, pharmacists collaborate with governmental and non-governmental entities to endorse legislative actions, research endeavors, and educational schemes focused on mitigating AMR and safeguarding the efficacy of antimicrobial agents (6).

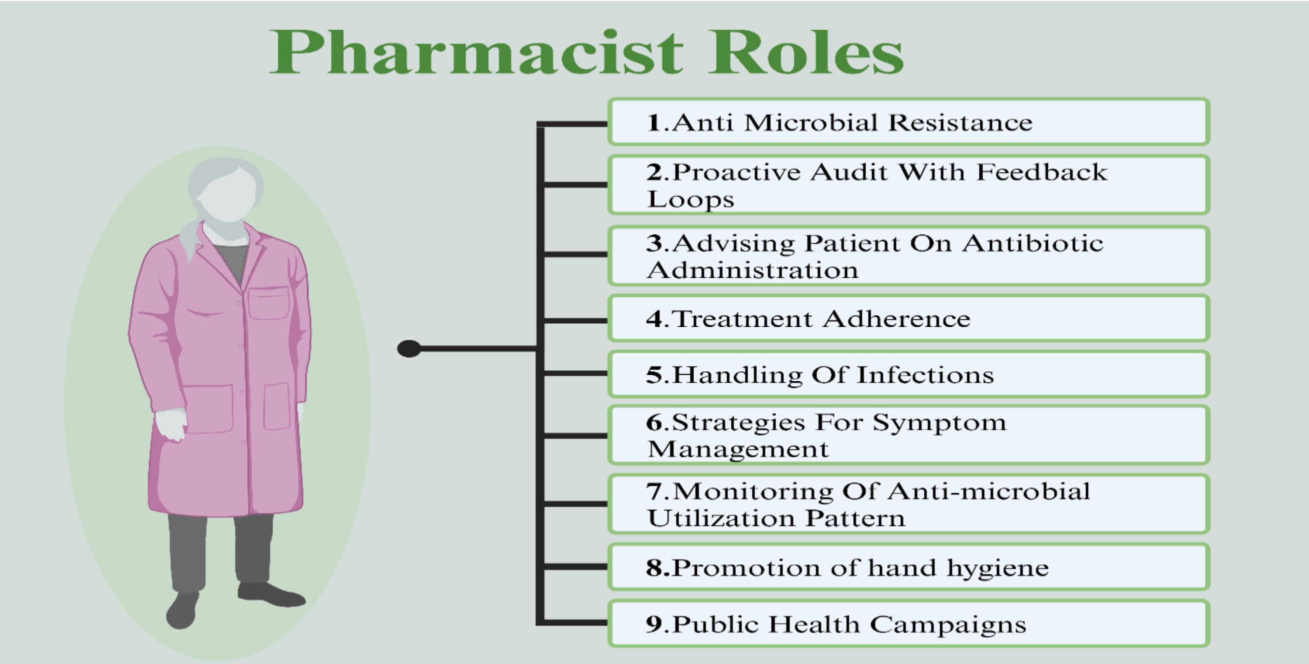

Figure 1: The multifaceted contributions of pharmacists in combatting antimicrobial resistance (AMR).

1.2 Purpose and Scope of the Review:

This review endeavors to offer a thorough examination of the dynamic involvement of pharmacists in combating AMR, with a particular emphasis on their role in antimicrobial stewardship, patient education, infection prevention and control, and advocacy for public health. The review encompasses an analysis of the multifaceted contributions of pharmacists within these domains.

Pharmacist-led interventions: This section delves into targeted interventions orchestrated by pharmacists aimed at promoting responsible antimicrobial use and attenuating AMR.

Interdisciplinary collaboration: Here, we scrutinize the integral role pharmacists play within interdisciplinary healthcare teams, underscoring their collaborative efforts to refine antimicrobial therapy and bolster infection prevention strategies.

Global perspectives: An assessment of global initiatives and policy frameworks that engage pharmacists in AMR mitigation efforts, with an emphasis on identifying effective practices and extracting lessons from diverse international contexts.

Technological innovations: This analysis highlights cutting-edge technological solutions that empower pharmacists to monitor antimicrobial consumption accurately, enhance adherence to clinical guidelines, and streamline communication across healthcare teams (5).

2. Innovative Practices in Antimicrobial Stewardship

Antimicrobial stewardship programs play a critical role in addressing the escalating challenge posed by AMR. Cutting-edge strategies within antimicrobial stewardship capitalize on technological progress, point-of-care testing, and personalized medicine methodologies to refine antimicrobial prescription practices, improve diagnostic precision, and counteract the proliferation of antimicrobial resistance (9). Technological progressions, such as the implementation of electronic health record (EHR) systems and the integration of clinical decision support systems (CDSS), facilitate instantaneous surveillance of antibiotic utilization and furnish evidence-grounded guidance for antimicrobial prescription practices (10). Point-of-care testing (POCT) provides swift diagnostic options for informing antimicrobial prescription choices, while personalized medicine strategies customize antimicrobial treatments according to individual patient attributes, thereby enhancing treatment efficacy and mitigating adverse effects and antimicrobial resistance. These novel methodologies hold significant promise in enhancing patient outcomes and addressing the pervasive challenge of multidrug-resistant infections on a global scale (11).

2.1 Technological Advancements:

Technological innovations have significantly transformed antimicrobial stewardship, providing advanced tools that optimize antimicrobial prescribing and enhance surveillance capabilities. These technological solutions include a variety of sophisticated systems that support healthcare professionals in addressing AMR. Notably, the integration of EHRs with antimicrobial stewardship applications enables the real-time monitoring of antibiotic use. This integration facilitates more precise and timely interventions, promoting the judicious use of antimicrobials and potentially mitigating the progression of AMR (12). These are the following technologies that are utilized for Antimicrobial Stewardship Table 1. Integration of antimicrobial stewardship tools into EHRs supports real-time surveillance of antibiotic prescribing patterns. This functionality is critical for promptly identifying deviations from recommended prescribing practices. By enabling such immediate oversight, EHR-integrated stewardship tools empower healthcare providers to implement precise, evidence-based interventions, thus enhancing the appropriateness of antibiotic usage (13).

Clinical Decision Support Systems (CDSS) represent a pivotal advancement in the field of antimicrobial stewardship through their integration of algorithm-driven analyses and data analytics. These systems meticulously process patient-specific data to furnish clinicians with evidence-based recommendations tailored to optimize antimicrobial prescribing practices (14). CDSS incorporates patient-specific variables, including age, comorbidities, and microbiological profiles, to facilitate informed clinical decision-making at the point of care. Additionally, CDSS enhances adherence to antimicrobial stewardship programs by aligning prescribing practices with established best practices and adapting to evolving patterns of antimicrobial resistance (15).

Advancements in Antimicrobial Susceptibility Testing (AST) have been significantly fortified by the integration of next-generation sequencing (NGS) technologies and automated AST systems. These innovative methodologies facilitate the expeditious identification of microbial pathogens and the assessment of their susceptibility to antimicrobial agents. Utilizing high-throughput sequencing coupled with sophisticated automated analytical algorithms, contemporary AST platforms equip healthcare professionals with precise and timely data critical for the formulation of effective antimicrobial therapies. This strategic application of tailored antimicrobial regimens, informed by the specific resistance profiles of the pathogens, plays a crucial role in curbing the emergence of antimicrobial resistance and enhancing patient treatment outcomes (16).

Matrix-assisted laser desorption/ionization time-of-flight mass spectrometry (MALDI-TOF MS) has emerged as a pivotal technology in clinical microbiology, facilitating the rapid identification of pathogens directly from clinical samples. By analyzing distinct protein spectra unique to various bacteria and fungi, MALDI-TOF MS enables precise organism identification (17). The expediency and accuracy of this method significantly shorten the duration required for microbial identification compared to conventional culturing techniques. Such prompt identification of pathogens is crucial, as it allows for the timely administration of targeted antimicrobial therapies, thereby improving patient outcomes. Moreover, this accelerated identification process reduces the reliance on broad-spectrum antibiotics, helping to combat antibiotic resistance by promoting the use of more specific treatments (18).

Using pharmacokinetic/pharmacodynamic (PK/PD) modeling within antimicrobial stewardship has emerged as a promising approach. These models help forecast how effective antibiotics will be in different parts of the body, considering factors like the organism's susceptibility, the drug's concentration over time, and the patient's characteristics. They're especially valuable in critical care settings, where getting the right dose of antibiotics quickly can make a life-or-death difference. By incorporating PK/PD models into stewardship programs, doctors can fine-tune dosing strategies to maximize effectiveness while minimizing the risks of toxicity and resistance (19).

Incorporating artificial intelligence (AI) and machine learning (ML) algorithms into antimicrobial stewardship is an emerging field with promising applications. These technologies leverage extensive datasets encompassing factors such as drug resistance patterns, patient characteristics, and clinical outcomes to predict optimal antimicrobial therapies. Moreover, they can anticipate forthcoming resistance trends, facilitating proactive stewardship interventions. Through iterative learning from real-world data, these AI systems enhance their predictive precision over time, thereby establishing themselves as integral elements of contemporary antimicrobial stewardship paradigms (20).

Table 1: Summary of technological advancements in antimicrobial stewardship.

Technology	Description
EHR Integration	EHRs allow real-time monitoring of antibiotic prescriptions.
Clinical Decision Support	Algorithm-driven systems that process patient-specific data to provide evidence-based recommendations for optimizing antimicrobial prescribing practices.
Next-Gen AST	Integration of NGS and AST expedites pathogen identification and susceptibility assessment.
MALDI-TOF MS	Rapid technology for identifying pathogens directly from clinical samples based on unique protein spectra, reducing reliance on broad-spectrum antibiotics
PK/PD Modeling	Predictive modeling to optimize antibiotic dosing strategies, considering factors like drug concentration, susceptibility, and patient characteristics.
AI and ML	Integration of AI and ML algorithms for predicting optimal antimicrobial therapies and anticipating resistance trends.

2.2 Point-of-Care Testing and Interventions:

Point-of-care testing (POCT) has become a crucial aspect of antimicrobial stewardship programs, providing rapid diagnostic solutions for timely decision-making at the patient's bedside or in clinical settings. With the ability to deliver actionable results within minutes, POCT facilitates targeted antimicrobial therapy, reduces unnecessary antibiotic use, and optimizes patient management (21). This section explores the significance of POCT and its key interventions in greater detail.

Rapid Diagnostic Tests (RDTs) represent a transformative advancement in the field of infectious disease diagnosis, offering timely results at the point of care. RDTs present a promising avenue for swiftly and precisely detecting infectious agents and assessing antimicrobial resistance (22). These tests, exemplified by those for influenza and urinary tract infections, enable swift identification of viral or bacterial pathogens, facilitating prompt initiation of targeted antimicrobial therapy by healthcare providers. Through the differentiation of bacterial and viral origins, RDTs contribute significantly to the reduction of antibiotic overuse for viral infections, thus safeguarding antimicrobial effectiveness and mitigating the emergence of antimicrobial resistance (23).

Biomarker-driven methodologies utilize distinct biomarkers like procalcitonin and C-reactive protein to assist clinicians in discerning between bacterial and non-bacterial infections. Heightened concentrations of these biomarkers commonly signify bacterial infections, informing decisions regarding antimicrobial prescription. Through the integration of biomarker testing into clinical settings, practitioners can enhance the utilization of antibiotics, diminish unwarranted prescriptions, and mitigate the development of antimicrobial resistance (24). This precision-guided strategy aids in mitigating superfluous antibiotic administration for viral illnesses, thereby diminishing the probability of antimicrobial resistance emergence while concurrently enhancing patient care.

Emerging POCT platforms, encompassing molecular diagnostics and biosensors, present unparalleled capacities for swift and precise pathogen and antimicrobial resistance marker detection. These cutting-edge technologies empower healthcare practitioners to promptly discern infectious agents and their resistance patterns, thereby enabling tailored antimicrobial treatments and well-informed clinical decisions. Through bolstering surveillance initiatives and guiding antimicrobial stewardship measures, novel POCT platforms serve as pivotal assets in the battle against antimicrobial resistance, ultimately augmenting patient prognoses (25).

POCT heralds a transformative approach in diagnostic assessment, affording clinicians the ability to formulate real-time, evidence-driven decisions. Through its capacity to streamline targeted antimicrobial interventions, curtail superfluous antibiotic administration, and bolster surveillance methodologies, POCT emerges as a focal asset in advancing antimicrobial stewardship objectives and combatting the proliferation of antimicrobial resistance.

2.3 Personalized Medicine:

Personalized medicine has surfaced as a prospective avenue within antimicrobial stewardship, endeavoring to customize antimicrobial treatment according to individual patient attributes. By assimilating patient-specific variables and genetic data into therapeutic determinations, personalized medicine strives to enhance treatment efficacy while mitigating adverse reactions and the emergence of antimicrobial resistance (26).

Pharmacogenomics stands as a cornerstone in the realm of personalized medicine within antimicrobial stewardship, offering invaluable insights into how individual genetic variations impact drug metabolism and treatment response. Integrating pharmacogenomic data into antimicrobial stewardship programs empowers clinicians to tailor dosing regimens to match the unique genetic profiles of patients, thereby optimizing therapeutic outcomes while minimizing the risk of adverse drug reactions (27). This approach ensures that antibiotics are administered at doses most likely to be effective based on individual genetic characteristics, thus enhancing treatment efficacy and patient safety. For instance, variations in drug-metabolizing enzymes like cytochrome P450 can significantly influence the metabolism of certain antibiotics, necessitating dose adjustments to achieve optimal drug concentrations in the body. By harnessing pharmacogenomic information, clinicians can personalize antibiotic therapy to maximize efficacy while minimizing the potential for toxicity or treatment failure. Pharmacogenomics offers a promising avenue for individualizing antimicrobial therapy, representing a key component of personalized medicine in antimicrobial stewardship (28).

Precision antibiotic therapy plays a pivotal role in the realm of personalized medicine within antimicrobial stewardship, providing a customized strategy for antibiotic treatment that takes into account unique patient attributes and the distinct traits of the infecting pathogen. This methodology strives to enhance treatment efficacy while mitigating adverse effects and the emergence of antimicrobial resistance (29). Fundamentally, precision antibiotic therapy entails the selection of antibiotics based on the susceptibility profile of the causative pathogen. Utilizing microbiological assessments, such as culture and sensitivity testing, enables the identification of the specific pathogen responsible for the infection and its susceptibility to various antibiotics. Armed with this information, clinicians can opt for antibiotics that exhibit the highest likelihood of efficacy against the infecting organism, thereby enhancing treatment effectiveness and diminishing the likelihood of treatment failure or the emergence of antimicrobial resistance (30). Precision antibiotic therapy considers specific patient characteristics that may impact antibiotic effectiveness and safety. Patients with impaired renal or hepatic function, for example, may require dosage changes to attain therapeutic medication levels without causing toxicity (31). Tailoring antibiotic therapy to the unique patient attributes and the specific traits of the infecting pathogen represents a pivotal advancement in medical precision. This approach optimizes antimicrobial stewardship endeavors by fostering prudent antibiotic administration and mitigating superfluous usage.

Therapeutic Drug Monitoring (TDM) is an essential aspect of personalized medicine within antimicrobial stewardship, allowing for the customized adjustment of antimicrobial dosing regimens based on the analysis of drug concentrations in patient samples. Through the continuous monitoring of drug levels in the blood or other bodily fluids, TDM ensures that therapeutic concentrations are maintained to achieve the best possible treatment outcomes while minimizing the risk of toxicity or inadequate dosing. This personalized approach enables clinicians to tailor antimicrobial therapy to suit the specific needs of each patient, taking into account factors such as renal or hepatic function, drug interactions, and variations in drug metabolism. TDM plays a crucial role in optimizing treatment outcomes, especially in patients with altered pharmacokinetics or compromised organ function, where standard dosing regimens may not be sufficient or may increase the likelihood of adverse effects. By providing timely feedback on drug levels, TDM assists clinicians in making informed decisions regarding dosage adjustments, ultimately improving the effectiveness and safety of antimicrobial therapy while reducing the development of antimicrobial resistance (26).

3. Integration of Pharmacists in Interdisciplinary Teams

In the fight against AMR, the involvement of pharmacists within interdisciplinary teams plays a pivotal role. AMR represents a formidable global health challenge wherein microorganisms such as bacteria, viruses, fungi, and parasites evolve to resist the effects of medications, rendering infections more difficult to manage and increasing the likelihood of disease transmission, severe health consequences, and fatalities (32). By incorporating pharmacists into the multifaceted approach to AMR mitigation, several significant advantages emerge. These include an enhancement in patient outcomes, stemming the proliferation of resistant strains, and generating substantial cost savings (33) (34). This integration capitalizes on the unique expertise of pharmacists, ensuring optimized medication management, adherence, and stewardship, thereby fortifying the arsenal against AMR. Furthermore, their involvement fosters collaborative decision-making processes within healthcare teams, promoting holistic patient care and bolstering antimicrobial stewardship initiatives. As pharmacists are ideally positioned at the frontline of healthcare delivery, their active engagement in combating AMR is indispensable, underscoring the imperative for their integration within interdisciplinary frameworks aimed at curbing this pressing public health threat (6).

Pharmacists serve as integral pillars within healthcare teams, wielding significant influence in medication management and offering crucial guidance on the appropriate utilization of medicines (35). The education and training imparted to pharmacists possess the capacity to shape the conduct of fellow healthcare professionals and individuals seeking healthcare services (36), forming a multifaceted approach aimed at transforming practices and upholding the optimal utilization of antibiotics (37). Positioned strategically, pharmacists possess the capability to enhance comprehension regarding antibiotics and promote their prudent administration through direct engagement with community members (38) and within hospital settings (39). This direct interaction allows for personalized education on antibiotic usage, empowering individuals to make informed decisions regarding their healthcare needs. Additionally, within hospital environments, pharmacists contribute to antibiotic stewardship initiatives, working collaboratively with healthcare teams to optimize antibiotic prescribing practices and ensure the delivery of high-quality patient care (40). This underscores the pivotal role of pharmacists in championing the judicious use of antibiotics and underscores their significance in safeguarding public health against the threat of antimicrobial resistance.

3.1 Case Studies Demonstrating Pharmacists' Crucial Role in Combatting Antimicrobial Resistance

In both hospital and community settings, pharmacists occupy a pivotal role as key stakeholders in combatting AMR. Their involvement encompasses the implementation of diverse strategies aimed at mitigating this pressing public health concern. Many case studies have been conducted, delineating pharmacist importance in reducing or preventing AMR. These case studies provide valuable insights into the efficacy of different methodologies in reducing the incidence of AMR. A study conducted by Sakeena et al. delves into the pressing global issue of AMR and its disproportionate impact on developing countries. It underscores the pivotal role that healthcare workers, particularly pharmacists, can play in advocating for the appropriate use of antimicrobials to mitigate AMR. The objective of the study is to examine the involvement of pharmacists in guiding antibiotic usage and to explore avenues for bolstering their contributions to combat AMR in developing nations.

Through a comprehensive search of various databases, including MEDLINE, EMBASE, Web of Science, and Google Scholar, the researchers scrutinized articles published between 2000 and August 2017. The key findings reveal a disparity in the extent of pharmacist involvement in patient care between developing and developed countries. While pharmacists in developed nations have expanded their roles, providing diverse services that lead to improved health outcomes and cost reductions, those in developing countries have more limited engagement. However, success stories from pharmacist-led initiatives in developed countries demonstrate the potential for appropriately trained pharmacists to play a significant role in addressing AMR globally. These pharmacists can educate patients on the proper use of antibiotics and offer guidance to healthcare colleagues regarding appropriate prescribing practices. In conclusion, the study underscores the importance of integrating well-trained pharmacists into the healthcare system of developing countries to mitigate inappropriate antibiotic use, thereby contributing positively to the global fight against AMR. Strengthening and enhancing the role of pharmacists in these settings holds promise for addressing this critical public health challenge (5).

In Another study conducted by Yan Chan et al. explored the involvement of pharmacists in AMS and their attitudes toward AMR across various countries. Through a cross-sectional survey distributed via the Commonwealth Pharmacists' Association and related networks, data were gathered from 546 pharmacists representing 59 countries, with a significant portion from Africa, Asia, and Oceania. Findings revealed that pharmacists supplied an average of 46 antibiotic prescriptions per week, with 73% of these dispensed in response to a prescription. Notably, 60.2% of respondents admitted to dispensing antibiotics without a prescription at least once. Despite this, pharmacists demonstrated good knowledge of antibiotics and held positive beliefs about AMR. Interestingly, there was a positive correlation between knowledge of antibiotics and beliefs about AMR. Factors such as country income and work setting influenced these beliefs, with pharmacists from lower-income countries more likely to supply antibiotics without a prescription. Conversely, those with more positive attitudes towards AMR were less likely to do so. Overall, the study highlights the need for continued education and support for pharmacists worldwide to strengthen their role in antimicrobial stewardship efforts and mitigate the global threat of AMR (41).

Another study conducted by Ellis et al. aimed to evaluate the impact of pharmacist intervention on the appropriateness of antimicrobial prescribing within a geriatric psychiatric unit (GPU). Patients aged 18 and above who were prescribed oral antibiotics during GPU admission were included in the analysis. The study compared antimicrobial appropriateness before and after pharmacist intervention. During both the six-month pre- and post-intervention phases, 63 and 70 patients, respectively, were identified as prescribed antibiotics. The findings revealed that following the intervention, the post-intervention group had significantly fewer inappropriate doses for indication compared to the pre-intervention group, as well as a significant decrease in antibiotics prescribed for an inappropriate duration. While there were no notable differences in the use of appropriate drugs for indication or appropriate doses for renal function between the groups, there was a significant increase in patients receiving medications with appropriate dose, duration, and indication post-intervention. Overall, pharmacist intervention was associated with a notable reduction in inappropriate antimicrobial prescribing rates within the geriatric psychiatric unit (42).

In another study performed by Nasr et al., they aimed to explore pharmacist-driven interventions in patients with COVID-19 and their impact on antimicrobial use, considering the potential for misuse exacerbating AMR. Using the Joanna Briggs Institute's manual framework for scoping reviews, the study identified eleven publications focusing on AMS interventions performed by pharmacists in COVID-19 patients. These interventions primarily included pharmacist-driven initiatives, guideline development, and medication supply coordination. Results indicated a reduction in antimicrobial use and prevention of adverse drug reactions, with pharmacist-led interventions garnering relatively high acceptance rates from physicians. Overall, pharmacists emerged as key players in combating AMR during the pandemic, with their interventions showing positive impacts on antimicrobial use and patient outcomes in COVID-19 cases (43).

A study conducted by Qamariat et al. delved into the role of pharmacists in combating AMR in Saudi Arabia, a country grappling with the emergence of this issue. Employing a cross-sectional design, the study utilized an online questionnaire to gather insights into the enablers and barriers experienced by pharmacy personnel in addressing AMR, along with strategies to overcome these challenges. Among the 109 participants, the majority were female pharmacists with several years of work experience. Most participants reported having antimicrobial stewardship programs in place and were actively involved in managing infectious diseases during the COVID-19 pandemic. Findings revealed that pharmacists perceived preparatory tasks, education, and self-directed learning related to AMR as natural aspects of their role. However, they encountered various barriers such as insufficient education and training opportunities, limited time, and restricted access to educational resources. On the other hand, participants identified continuing professional development activities, funded educational programs, and accessible resources as key enablers to enhance their capacity to address AMR. The study concluded that addressing barriers to AMR management requires providing pharmacists with adequate time for self-directed learning, access to educational tools and resources, and opportunities for funded training programs to equip them with the necessary knowledge and skills (44).

Another example of a study conducted by Rusic et al. aimed to assess the attitudes and knowledge of pharmacists and physicians regarding antimicrobial treatment and resistance, with a focus on identifying potential gaps and opportunities for collaboration between the two professions. Questionnaires were administered to both groups, covering various aspects such as prescribing/dispensing behaviors, perceptions of contributors to AMR, self-rated preparedness for practice actions, and knowledge assessment. The study involved 180 community pharmacists and 181 physicians, revealing that a significant proportion of physicians would prescribe antimicrobials when unsure of the infection's etiology. Family medicine doctors were commonly perceived as the greatest contributors to AMR, followed by patients. Notably, physicians demonstrated higher knowledge scores compared to pharmacists. The findings underscored the need for improved practices among both professions and highlighted the importance of patient consultation in antimicrobial prescribing and dispensing to mitigate their contribution to AMR (45).

A study conducted by Fay et al. sought to investigate the impact of implementing a pharmacist-led ASP in urgent care (UC) settings, an area that has been relatively understudied compared to inpatient and emergency department (ED) environments. Through a retrospective quasi-experimental approach, the study focused on UC patients with positive urine or wound cultures post-discharge. Following the implementation of a collaborative practice agreement in 2015, pharmacists were empowered to lead UC culture follow-up using a stewardship-focused protocol. The primary objective was to compare guideline-concordant antibiotic prescribing rates before and after the ASP implementation. Results showed significant improvements in both overall guideline-concordant prescribing and antibiotic selection post-ASP. Although there was a trend towards fewer patients requiring follow-up and a longer median time to follow-up in the post-ASP group, these differences were not statistically significant. Importantly, there were no notable differences in UC or ED revisits within 72 hours or hospital admissions within 30 days between the pre-and post-ASP groups. In conclusion, the study highlighted the effectiveness of a pharmacist-led UC ASP in enhancing guideline-concordant antimicrobial prescribing practices. The above studies are certain examples of pharmacists influencing AMR practices. The

Table 2 below is a detailed explanation of the case studies.

Table 2: A detailed description of case studies about Pharmacist's role in influencing AMR practices.

Authors	Setting	Objective	Outcomes	Interdisciplinary involvement	Results	Conclusion
Sakeena et al (5)	Community and Hospital settings in developed countries	To investigate the role of pharmacists in the appropriate use of antibiotics and to identify how the pharmacists' role can be enhanced to combat AMR in developing countries	Appropriate use of Antibiotics, the role of pharmacist to combat AMR.	Pharmacists	In developing nations, pharmacists play a modest role in patient care, whereas in developed countries, their involvement is more extensive, leading to better health outcomes and cost savings. Pharmacists educate patients on antibiotic use and advise healthcare peers on prescribing practices.	This review emphasizes that well-trained pharmacists integrated into healthcare systems can significantly reduce inappropriate antibiotic usage in developing nations.
Yan-chan et al (41)	Across various countries	To explore how pharmacists across the world perceive AMR and antimicrobials, and how these beliefs influence antibiotic supply practices	Antibiotic supply practices, Beliefs about AMR, Knowledge	Healthcare professionals	Respondents exhibited good knowledge (mean score: 9.6 out of 12) and positive beliefs about antimicrobial resistance (mean score: 3.9 out of 5). However, individuals from lower-income countries had significantly higher odds (7.4 times) of supplying antibiotics without a prescription. Conversely, holding more positive beliefs about antimicrobial resistance was associated with lower odds of supplying antibiotics without a prescription.	The majority of pharmacists exhibited strong knowledge of antibiotics and maintained optimistic views regarding AMR. These perspectives were shaped by variables like expertise, workplace dynamics, and economic status.
Ellis et al (42)	Academic medical center	To evaluate how pharmacist involvement influences the suitability of antimicrobial prescription practices within a geriatric psychiatric unit (GPU).	Antimicrobial appropriateness	-	Significantly fewer inappropriate doses for indication compared to the pre-intervention group (10.6% vs. 23.9%, $p = 0.02$), and fewer antibiotics prescribed for an inappropriate duration (15.8% vs. 32.4%, $p < 0.01$), more patients in the post-intervention group had medications prescribed with appropriate dose, duration, and indication (51% vs. 66%, $p = 0.04$)	This project exemplifies a multi-disciplinary approach to enhance antimicrobial prescribing without a formal stewardship program. It notably improved evidence-based selection of antimicrobial duration.
Nasr et al (43)	Clinical setting	This review aimed to characterize pharmacist-driven interventions that have been performed in patients with COVID-19 globally and describe their impact on antimicrobial use.	Impact of AMS interventions	Pharmacist-driven	The most common AMS intervention was pharmacist-driven interventions reported in 63.2% of all studies, followed by guideline development and application (26.3%), and medication supply coordination (10.5%), respectively.	Pharmacists played an important role in performing AMS-related interventions in COVID-19 patients and helped in the fight against the worsening of AMR during the pandemic.
Qamariat et al (44)	Ministry Health Hospital Pharmacies	To determine Pharmacists' Perceptions of Handling AMR	-	Registered Pharmacist practicing in Ministry of Health hospitals	Pharmacists identified various factors such as preparatory tasks, education, experience, and self-learning as natural components related to handling AMR, with an average score of 3.2. Conversely, barriers like inadequate background, limited training, time constraints, and lack of educational resources were deemed relevant, with an average score of 4.05. On the other hand, enablers such as continuous professional development (CPD) activities, accessible resources, and competency evolution were also considered relevant, with an average score of 4.12.	The study found that overcoming barriers to addressing AMR requires granting pharmacists additional time for self-directed education, access to online resources, and offering funded courses to enhance their knowledge and skills in managing AMR.
Rusic et al (45)	-	To evaluate pharmacists' and physicians' attitudes and knowledge about antimicrobial treatment and resistance and based on the results to identify possible gaps and suggest opportunities for collaboration between the two professions.	Prescribing/Dispensing Behaviors, Perceptions of Contributors to AMR, Knowledge Assessment.	Physicians and Pharmacist	Approximately 42% of physicians admitted they would prescribe antimicrobials when unsure if an infection was viral or bacterial, indicating a potential area of concern for antimicrobial stewardship. Moreover, a majority of participants viewed family medicine doctors as the primary contributors to antimicrobial resistance (59.8%), closely followed by patients (48.5%). In terms of knowledge, physicians outperformed pharmacists significantly, highlighting a disparity between the two professions in understanding antimicrobial treatment and resistance.	This research revealed practices among pharmacists and physicians that should be improved and it highlighted gaps in knowledge by both professions.
Fay et al (46)	Urgent care setting	To determine the impact of implementing a pharmacist-led ASP in the UC setting.	total guideline-concordant antibiotic prescribing.	Pharmacist-led	In the post-ASP group, guideline-concordant prescribing increased significantly to 53.3% compared to 41.3% in the pre-ASP group. Additionally, guideline-concordant antibiotic selection improved from 51% to 68% post-ASP. Follow-up was required for fewer patients post-ASP (10.7%) compared to pre-ASP (18%). The median time to follow-up calls increased to 71 hours post-ASP compared to 38 hours pre-ASP. No significant differences were found in UC and ED revisits within 72 hours or hospital admissions within 30 days between the pre-and post-ASP groups.	A pharmacist-driven urgent care antimicrobial stewardship program resulted in notably enhanced adherence to prescribing guidelines for antibiotics.

3.2 Role of Pharmacist in Public Health Initiatives in Reducing AMR

Pharmacists play a crucial role in public health campaigns and education programs aimed at reducing AMR. As medication experts, pharmacists are well-positioned to educate both healthcare professionals and the public about the prudent use of antibiotics and other antimicrobial agents. They serve as frontline healthcare providers, often being the first point of contact for individuals seeking medical advice in community settings (47). In these campaigns and programs, pharmacists disseminate vital information about the appropriate use of antibiotics, emphasizing the importance of completing prescribed courses and avoiding unnecessary or inappropriate antibiotic use. They also highlight the consequences of AMR, such as increased treatment costs, prolonged illness, and higher mortality rates, underscoring the urgent need for action (48). Moreover, pharmacists engage in collaborative efforts with other healthcare professionals, including physicians and nurses, to promote antimicrobial stewardship initiatives. This involves implementing strategies to optimize antimicrobial use, such as antimicrobial stewardship programs in healthcare facilities and promoting the use of alternative therapies where appropriate (49).

The goal of the ASP is to maximize the use of antibiotics; training and education enhance the efficacy of ASP initiatives in hospitals (50). One useful strategy for encouraging the responsible use of antibiotics is educational intervention (51) (52) (53). Research conducted at the National Liver Institute in Egypt introduced an educational initiative to healthcare providers alongside the ASP. This intervention resulted in noticeable enhancements in the knowledge, attitudes, and behaviors of healthcare providers (54). Various other studies have also shown significant improvements in the rational utilization of antibiotics after the educational intervention, particularly led by pharmacists (55) (56).

An example of a study conducted by Gilham et al. delved into the effectiveness of public health campaigns targeting AMR and antibiotic usage behavior. These campaigns, aimed at altering behavior by raising awareness, face complexities due to the intricate nature of AMR. The study aimed to identify effective campaigns and assess the outcome measures used to gauge their effectiveness. Through a systematic search of Ovid MEDLINE and Embase, covering studies published between 2010 and September 2022, 41 studies and 30 unique interventions were included. The majority of campaigns were conducted in Europe, predominantly at a national level, and targeted adult members of the public or both the public and healthcare professionals. The primary focus of these campaigns was to enhance knowledge and attitudes towards AMR. Effective campaigns often utilize mass media, targeted messaging for specific infections, and healthcare professional-patient interactions. Despite variations in study designs, some common themes emerged among effective campaigns. However, the reliance on observational study designs complicates establishing causation between campaigns and changes in outcome measures. The study underscores the importance of incorporating clear evaluation processes into campaign design, suggesting the development of a campaign evaluation framework to facilitate this endeavor (57).

4. Economic and Policy Implications

The concept of pharmacists taking a leading role in antibiotic stewardship encompasses examining the economic and policy-related ramifications of such initiatives. This approach involves exploring how pharmacists can help optimize antibiotic use, thus potentially reducing the spread of antibiotic resistance, lowering healthcare costs, and enhancing patient outcomes (58). This topic also considers the necessary policies to support pharmacists in these roles and evaluates the financial impacts on healthcare systems. By analyzing these aspects, we can better understand the value and implications of integrating pharmacists more deeply into efforts aimed at prudent antibiotic management.

4.1 Cost-Effectiveness of Pharmacist Interventions:

Antibiotic stewardship programs led by pharmacists involve pharmacists taking an active role in managing and monitoring antibiotic usage in healthcare facilities. This strategy not only optimizes the allocation of resources but also curtails financial burdens stemming from inappropriate antibiotic prescriptions (59). By ensuring that antibiotics are prescribed only when necessary and in the correct dosages, these programs help prevent the development of antibiotic resistance, further reducing long-term healthcare costs and improving patient outcomes (60). Pharmacists play a crucial role in ensuring antibiotics are used judiciously, which in turn helps mitigate the rise of antibiotic resistance—a major public health issue. This resistance can lead to prolonged hospitalizations, more severe medical conditions, and increased medical expenses (61). The economic advantages of these initiatives are further seen in reduced sickness-related absenteeism, promoting better workforce productivity and overall economic health (62). Additionally, by controlling the spread of drug-resistant infections, these stewardship programs maintain the effectiveness of current antibiotics, thereby postponing the costly development of new medications. These programs are increasingly recognized to improve patient outcomes (63). Thus Assessing the cost-effectiveness of these interventions is crucial, especially in light of the urgent necessity to enhance healthcare expenditure efficiency while tackling antimicrobial resistance. The cost-effectiveness programs focus on Reduction in Antimicrobial Costs, Decrease in Resistance and Associated Costs, Impact on Hospitalization and Readmission Rates, Long-Term Cost Savings and Health Outcomes, and Investment in Training and Development (64) (65) (**Error! Reference source not found.**).

A study conducted by Wang et al. investigated the impact of pharmacist-driven antimicrobial stewardship programs on antibiotic usage and costs in a Chinese hospital setting. The research focused on hepatobiliary surgery and respiratory wards, implementing interventions like prescription audits, restrictions, and staff education. Results showed significant reductions in hospital stays, antibiotic consumption, and costs, particularly in the hepatobiliary surgery ward. However, broad-spectrum antibiotic misuse remained a concern. The study underscores the effectiveness of pharmacist-led stewardship in improving antibiotic use appropriateness, such as reducing irrational prescriptions and enhancing timely treatment adjustments. It emphasizes the need for sustained education for pharmacists and increased governmental support to ensure the longevity and efficacy of such programs (66).

In another example of a study conducted in a 194-bed hospital without infectious diseases physicians, and pharmacists led an ASP. They aimed to assess the program's impact on antimicrobial use and its clinical and economic implications using the CLEO tool. Through a prospective quasi-experimental study, they measured changes in antimicrobial use, proposing 847 pharmacist interventions (PIs) with an acceptance rate of 88.3%. Most PIs focused on discontinuing antibiotics due to excessive duration. The program significantly reduced overall antimicrobial consumption, particularly carbapenems and quinolones, leading to a decrease in direct antibiotic expenditure. The study concludes that pharmacist-led ASPs are effective in optimizing antibiotic use, even without ID physician support, suggesting pharmacists' potential to improve antimicrobial stewardship in small hospitals (67).

A similar study conducted by Leache et al. investigated the effects of incorporating a clinical pharmacist into the Intensive Care Unit (ICU) to intervene in antimicrobial usage. Through a retrospective observational study spanning five months, they identified drug-related problems and medication errors in ICU patients. The pharmacist intervened for each problem, with the majority of interventions significantly improving patient care. Physicians accepted nearly all interventions. The study found a potential cost saving of €10,905 due to pharmacist interventions, demonstrating a positive impact on patient care and cost reduction in the ICU. The findings suggest that integrating clinical pharmacists into ICU teams can be both clinically beneficial and economically advantageous (68).

Another research study conducted by Gebretekle et al. assessed the cost-effectiveness of implementing AMS at Tikur Anbessa Specialised Hospital (TASH) in Ethiopia. They developed a model to compare pharmacist-led AMS with strengthened laboratory capacity to usual care. The study, from a societal perspective, demonstrated that the AMS strategy was associated with significant cost savings and improved patient outcomes, including an expected gain in quality-adjusted life-years (QALYs) and a reduction in healthcare costs. The findings suggested that despite the need for additional initial investments, the laboratory-supported pharmacist-led AMS program was economically advantageous in a low-resource setting like TASH. Sensitivity analyses indicated that the program remained cost-effective across a range of scenarios, making a compelling case for its implementation in similar healthcare settings to improve patient care and reduce healthcare costs (69). The studies demonstrate the positive impact of Pharmacist-led cost effectiveness programs in different healthcare settings in different areas of the world.

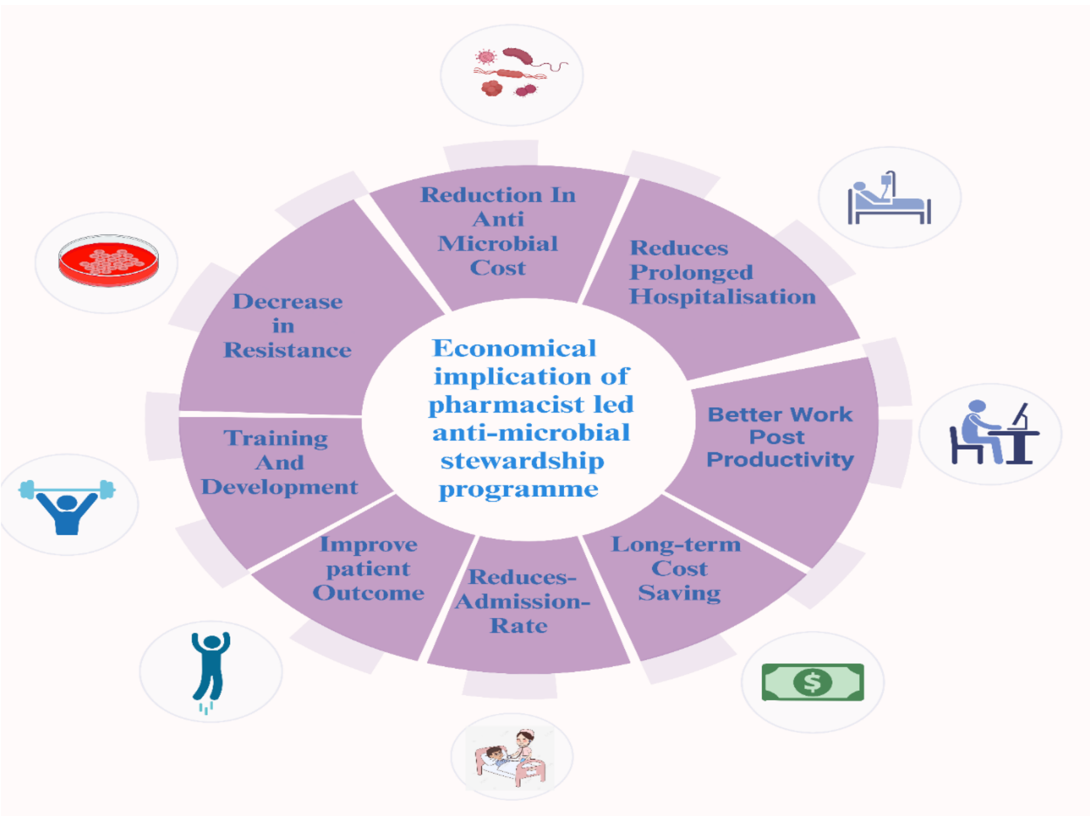

Figure 2: Economic Impact of Pharmacist-led Antimicrobial stewardsips programmes.

4.2 Policy Frameworks

ASPs are crucial in healthcare settings for managing and optimizing the use of antibiotics. The involvement of pharmacists in these programs is increasingly recognized due to their expertise in medication management and pharmacotherapy. A well-structured policy framework for pharmacist-led antimicrobial stewardship is essential to ensure effective implementation and success (70). Essential Elements of Regulations Supporting Pharmacists in Antimicrobial Stewardship: **Error! Reference source not found.**

Leadership and Governance:

Establishing clear leadership structures within pharmacist-led ASPs is paramount. Pharmacists occupying these roles typically oversee program coordination, data management, and collaboration with other healthcare professionals. Policy frameworks should delineate the scope of pharmacist responsibilities, including decision-making autonomy and reporting mechanisms. This clarity in defining roles ensures pharmacists can efficiently execute their duties, fostering effective teamwork and communication essential for optimizing antimicrobial use and patient care (71).

Professional Development and Skill Enhancement:

Ongoing education and training are crucial elements of the framework for effective antimicrobial stewardship. It's essential that pharmacists continually update their knowledge with the most current information on antimicrobial treatments, emerging resistance trends, and stewardship tactics (72). Such continuous learning not only broadens their expertise but also empowers them to educate other healthcare professionals, patients, and caregivers on the proper use of antibiotics. This constant cycle of learning and teaching helps ensure that the latest insights and practices in antimicrobial management are disseminated widely, fostering a well-informed approach to antibiotic use across the healthcare spectrum (73).

Partnership and Interdisciplinary Strategy:

Effective antimicrobial stewardship requires collaboration across various departments and disciplines. Policies should facilitate and define the framework for multidisciplinary teamwork that includes infectious disease physicians, microbiologists, nursing staff, and hospital administration. This helps in creating a cohesive strategy and ensures that interventions are comprehensive and accepted across the board (74).

Policy and Protocol Development:

Standardizing practices throughout the organization requires the creation of particular policies and procedures. These protocols cover standards for microbiological testing, evaluation and feedback processes, and antibiotic usage guidelines. The overall results of treatment are improved and prescribing practices become less variable thanks to this standardization (75).

Monitoring and Reporting:

It is essential to regularly track and report on patterns of antibiotic usage and resistance. When it comes to gathering, examining, and interpreting information about antimicrobial usage and trends in resistance, chemists are essential. The policy ought to specify how and when the stewardship team and larger hospital committees will review the data, as well as how it will be used to educate and modify stewardship procedures (76) (40).

Quality Improvement:

Pharmacists are instrumental in leading improvement initiatives within the stewardship program. They can spearhead the integration of quality improvement procedures, setting standards, conducting audits, and establishing feedback loops. These measures allow for the measurement of intervention effectiveness and the identification of areas ripe for improvement, ultimately enhancing stewardship tactics (77) (78).

Thus By implementing a robust policy framework for pharmacist-led antimicrobial stewardships, healthcare institutions can significantly enhance the effectiveness of their ASPs, leading to better patient outcomes, reduced antimicrobial resistance, and overall improvement in healthcare quality and safety.

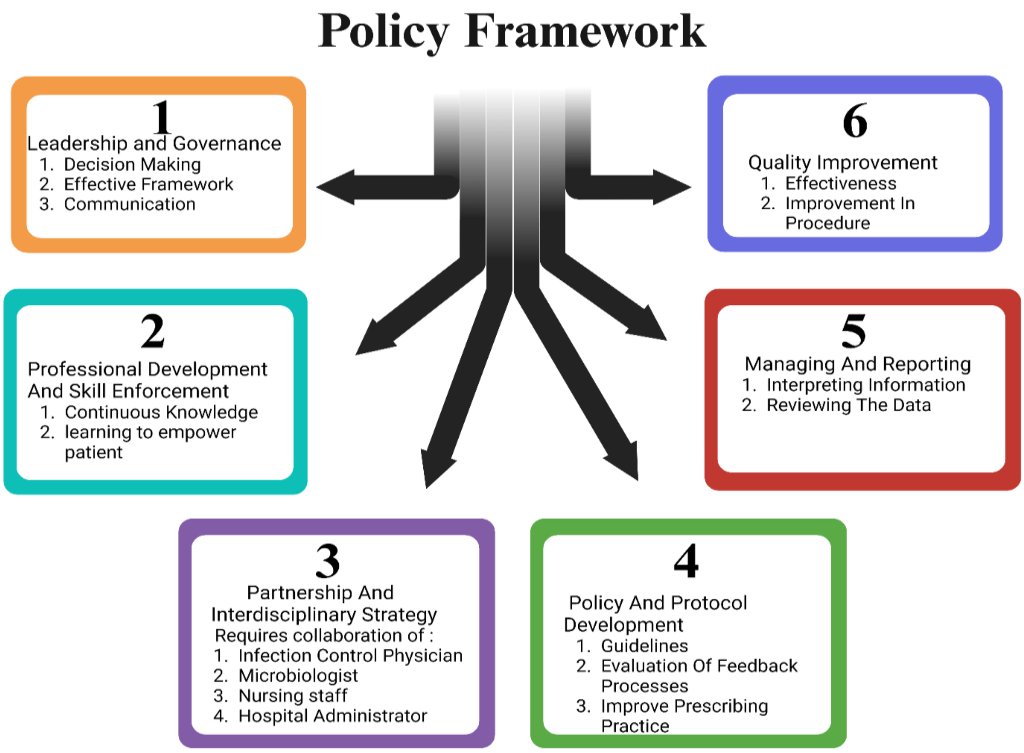

Figure 3: Implementation of a Robust Policy framewrok for a better Pharmacist-les Antimicrobial stewardship.

5. Challenges and Barriers to Further Integration

Within the framework of antimicrobial stewardship programs led by pharmacists, various hurdles exist within healthcare systems that can hinder the pharmacist's ability to make optimal contributions to efforts in antimicrobial stewardship. These challenges encompass a range of factors within healthcare systems that may impede the pharmacist's effectiveness in addressing AMR concerns and implementing stewardship initiatives (79) (80). Some of the challenges are discussed below:

Limited Authority and Recognition:

Pharmacists often encounter obstacles in being acknowledged as pivotal players in antimicrobial stewardship, stemming from hierarchical structures prevalent in healthcare systems. These structures may restrict their authority in making decisions regarding antimicrobial use, impeding their capacity to enact impactful stewardship interventions. Additionally, the expertise of pharmacists in antimicrobial management may not be adequately recognized, further hindering their effectiveness in addressing antimicrobial resistance concerns. Consequently, the limited acknowledgment of pharmacists' authority and expertise within healthcare systems presents a significant barrier to their ability to contribute effectively to antimicrobial stewardship efforts (81).

Resource Limitations:

Resource limitations, such as staffing deficiencies, restricted availability of diagnostic equipment, and financial restrictions, pose significant obstacles to pharmacists in executing comprehensive antimicrobial stewardship initiatives (82) (83). The absence of adequate support may hinder pharmacists' capacity to conduct thorough antimicrobial assessments, deliver educational sessions to healthcare personnel, and enact interventions aimed at enhancing antimicrobial utilization. These constraints compromise the effectiveness of antimicrobial stewardship programs led by pharmacists, limiting their ability to mitigate antimicrobial resistance and ensure optimal patient outcomes. Consequently, addressing these resource deficiencies is paramount to enabling pharmacists to fulfill their roles effectively in antimicrobial stewardship efforts.

IT barriers:

Healthcare systems often face limitations in information technology (IT), such as the absence of integrated EHR or specialized antimicrobial stewardship software (84). These deficiencies hinder real-time monitoring of antimicrobial use and impede communication among healthcare providers. Pharmacists are consequently challenged in accessing patient data, monitoring antimicrobial prescribing trends, and implementing interventions to optimize antimicrobial usage. The lack of robust IT infrastructure undermines the effectiveness of pharmacists in antimicrobial stewardship, as they are unable to leverage technological tools for data-driven decision-making and timely interventions (85). Therefore, addressing these IT limitations is crucial for enhancing pharmacists' roles in antimicrobial stewardship efforts.

Fostering Collaboration:

Collaboration across multidisciplinary healthcare teams is essential for successful antimicrobial stewardship. However, obstacles like hierarchical barriers, communication lapses, and professional isolation impede interprofessional communication and teamwork, hampering pharmacist-led endeavors (86) (87). The absence of effective collaboration impedes pharmacists' ability to involve prescribers, nurses, and other healthcare professionals in stewardship activities. Consequently, efforts to optimize antimicrobial use may be compromised, leading to challenges in addressing antimicrobial resistance (88). Overcoming these interprofessional collaboration barriers is critical for enhancing pharmacists' roles in antimicrobial stewardship and fostering a cohesive approach to combating antimicrobial resistance.

Managing Time Pressures:

Pharmacists frequently face time constraints due to heavy workloads and diverse responsibilities, which can curtail their involvement in antimicrobial stewardship activities. Juggling clinical duties, dispensing responsibilities, and stewardship initiatives poses a significant challenge, especially in environments characterized by high patient volumes or understaffed pharmacies (89). The limited time available for pharmacists to dedicate to stewardship efforts may compromise their ability to conduct thorough antimicrobial assessments, provide education to healthcare professionals, and implement interventions to optimize antimicrobial use (90). Addressing these time constraints is crucial for maximizing pharmacists' contributions to antimicrobial stewardship and ensuring comprehensive patient care.

Overcoming Prescriber Resistance:

Resistance to change from prescribers and healthcare providers presents a formidable obstacle to pharmacist-led antimicrobial stewardship endeavors. Clinicians' reluctance to alter prescribing behaviors or embrace stewardship guidelines stems from entrenched prescribing patterns, concerns regarding patient outcomes, or a sense of autonomy in decision-making. This resistance inhibits the adoption of stewardship recommendations and impedes efforts to optimize antimicrobial use. Pharmacists encounter challenges in engaging prescribers and healthcare professionals in stewardship initiatives, limiting their effectiveness in combating antimicrobial resistance (91). Overcoming this resistance to change is essential for fostering a culture of collaboration and ensuring the success of pharmacist-led antimicrobial stewardship programs (92).

Several case studies have been described further about challenges faced by ASPs:

A study conducted by researchers focused on identifying obstacles to establishing and executing hospital-based ASPs in tertiary care centers across three low- and middle-income countries (LMICs). Through interviews with 45 physicians in Sri Lanka, Kenya, and Tanzania, the study examined various factors influencing antimicrobial prescribing practices and ASP implementation. Key findings revealed common barriers including limited antimicrobial availability, resistance to changing prescribing practices, and inadequate diagnostic capabilities. Despite limited awareness of ASPs, most participants showed receptiveness to protocols involving documentation and ASP consultation. The study suggests addressing barriers through improved drug availability, enhanced access to microbiological data, local guideline development, and physician education on antimicrobial prescribing (93).

Another study conducted by Appaneal et alexamined the barriers and facilitators to antibiotic stewardship within Veterans Affairs (VA) medical centers, focusing on qualitative interviews with pharmacists. Despite the VA's leadership in antibiotic stewardship and the Centers for Disease Control and Prevention's (CDC) efforts to outline core elements for improved antibiotic use, challenges persist in implementing successful programs, especially in nonacute care settings. Through interviews with pharmacists from six VA medical centers in the VA New England Healthcare System, three main themes emerged: the importance of a supportive organizational culture, protected time for stewardship efforts, and a cohesive organizational structure. The study underscores the significance of leadership commitment, sufficient time allocation, and organizational cohesion in advancing and sustaining effective antibiotic stewardship programs, aligning with CDC core elements(94).

A similar study conducted by Mathew et al investigated the challenges of implementing AMS programs in secondary-level hospitals in LMIC contexts, focusing on experiences in Kerala, India. Employing qualitative methods, nodal officers were interviewed using a semi-structured guide to understand AMS implementation challenges. Results revealed various factors influencing antibiotic use, including patient expectations, physician practices, promotional activities, and hospital income dynamics. Challenges in sustainable stewardship programs encompass inter-doctor competition, time constraints, lack of leadership, and inadequate infrastructure. Discussion highlights the complexity of AMS in resource-limited settings, emphasizing the need for financial support, technological access, and capacity building. Addressing these challenges requires international collaboration, regulatory support, and tailored adaptation of stewardship models to LMIC contexts (95).

6. Future Directions and Recommendations

In anticipation of the dynamic trajectory of AMR mitigation, it is imperative to delineate future trajectories and offer recommendations essential for bolstering the involvement of pharmacists in combatting this ubiquitous health threat. Drawing upon the contemporary scholarly discourse, several pivotal domains emerge as focal points necessitating scrutiny: the imperative deployment of advanced training and educational interventions aimed at endowing pharmacists with requisite proficiencies in antimicrobial stewardship, infectious diseases, and pharmacotherapy, thereby fortifying their adeptness in navigating intricate AMR-centric scenarios (96). Incorporating pharmacists within primary care environments, including community pharmacies and outpatient clinics, is imperative for the extension of antimicrobial stewardship services and the enhancement of patient outcomes (97). Utilizing digital health technologies such as electronic health records and clinical decision support systems can optimize communication channels, streamline operational processes, and enable evidence-based decision-making within antimicrobial stewardship initiatives. Moreover, proactive involvement in research endeavors and surveillance protocols remains essential for monitoring antimicrobial consumption patterns, monitoring the emergence of resistance, and evaluating the efficacy of interventions in mitigating antimicrobial resistance prevalence (98).

Expanding Scope of Practice:

Expanding the pharmacists' sphere of practice within AMR management entails their integration into multidisciplinary teams focused on antimicrobial stewardship across healthcare facilities and community settings. In this augmented capacity, pharmacists engage in various activities, including conducting thorough medication reviews, offering evidence-based recommendations for antimicrobial therapy, and monitoring patient progress. Additionally, pharmacist-led interventions in community pharmacies are instrumental in promoting judicious antibiotic utilization and enhancing awareness of AMR among the populace. Leveraging their proficiency in medication management and patient education, pharmacists wield significant potential in influencing efforts to mitigate AMR and advancing public health outcomes (99).

Innovative Education and Training Models

Innovative educational and training frameworks are imperative in furnishing pharmacists with the requisite expertise and proficiencies to effectively tackle AMR. Indications propose that conventional pedagogical methodologies may fall short in adequately priming pharmacists to navigate the multifaceted landscape of AMR within clinical settings (5). Hence, there is an escalating demand for pioneering approaches aimed at augmenting pharmacists' comprehension of AMR and their proficiency in executing evidence-supported interventions. Continuing education initiatives and avenues for professional advancement significantly contribute to augmenting pharmacists' proficiency in managing AMR. These initiatives can be customized to target precise deficiencies in expertise or abilities identified through continual evaluation and feedback mechanisms. Notably, studies underscore the efficacy of interactive workshops and simulation activities in enhancing healthcare practitioners' compliance with antimicrobial prescribing protocols and mitigating unwarranted antibiotic utilization (100). Engaging in collaborations with public health entities and professional associations represents a pivotal tactic in advancing pharmacist education and training regarding AMR. Through these partnerships, the creation of online materials, toolkits, and protocols can be facilitated, offering pharmacists access to current evidence-based practices in AMR management. Furthermore, interprofessional training endeavors encompassing pharmacists, physicians, nurses, and other healthcare practitioners can cultivate a comprehensive approach to mitigating AMR while fostering synergistic decision-making in patient management (96). Innovative approaches to education and training play a pivotal role in equipping pharmacists with the necessary skills to effectively combat AMR. By incorporating AMR-focused material into pharmacy curricula, offering ongoing educational avenues, and fostering partnerships with public health bodies and professional associations, pharmacists can bolster their capacity as vital contributors to the battle against AMR.

Conclusion

In conclusion, pharmacists play a critical role in combating AMR through antimicrobial stewardship, patient education, infection prevention, and advocacy for public health. Their integration into interdisciplinary teams and utilization of technological advancements enhance their impact. However, challenges such as limited authority and resource constraints persist. To address these, policymakers must prioritize leadership, professional development, and partnership strategies to support pharmacists in their vital role. By fostering collaboration and innovation, pharmacists can continue to lead efforts in mitigating AMR and preserving the efficacy of antimicrobial agents for future generations. Antimicrobial resistance (AMR) constitutes a formidable global health challenge, undermining the efficacy of antibiotics essential for combating bacterial infections. This paper delineates the indispensable role of pharmacists, nursing in addressing AMR through multifaceted strategies, innovative approaches, and seamless integration into healthcare systems.

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Authors Contribution

All authors are involved and contributing in data collection, filtration and manuscript preparation including table, figures and final proof of manuscript.

Conflict of interest statement

Authors declare they do not have any conflict of interest.

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