The Intersection of Clinical Pharmacy, Microbial Resistance, and Public Health: Shaping Future Healthcare Policies

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Abstracts

Antimicrobial resistance (AMR) represents one of the most pressing global health challenges, resulting from the misuse and overuse of antibiotics in human medicine, agriculture, and environmental practices. This phenomenon threatens the efficacy of antibiotics, leading to increased mortality, longer hospital stays, and higher healthcare costs. This includes unprecedented role clinical pharmacists are playing for the war against AMR and their position on stewardship ASPs, educating patients and care providers, and formulating evidence-based policies. It goes on to discuss integrating the "One Health" approach by emphasizing connections between human, animal, and environmental health in attempting to check the rise in AMR; in this report, its economic and epidemiological effects, and call for greater collaboration and innovating new policy. The paper discusses critical interventions, including vaccination programs, stringent infection control measures, and enhanced surveillance systems. It then presents interdisciplinary research and technological advances as tools to drive solutions that are sustainable. This paper fosters a culture of collaboration through the expertise of clinical pharmacists and advocates for comprehensive and actionable strategies to address the issue of AMR while safeguarding global health.

Keywords: Antimicrobial resistance, Clinical pharmacy, Public health, One Health, Antimicrobial stewardship program, Healthcare policy, Infection prevention and control, Interdisciplinary scholarship.

1. Introduction

One of the key roles that clinical pharmacists have been educating healthcare professionals and patients on the proper use of antimicrobials. A study shows that pharmacists can correct misconceptions on the use of antibiotics, and this would help in rational prescribing (Sakeena et al., 2018). For example, Sakeena et al. focus on the role of pharmacists in developing countries by educating patients and directly intervening in reducing the inappropriate use of antibiotics (Sakeena et al., 2018). In addition, Hidayat et al. state that pharmacists have a very important role in identifying risk factors for resistant infections among patients and in designing antibiotic regimens based on evidence (Hidayat et al., 2012). This learning feature is essential, because various reports indicate that pharmacy graduates ask for more education related to stewardship of antimicrobial products, and it reveals some gap that must be met in pharmacy curriculums (Justo et al., 2014; Ahmed et al., 2019).

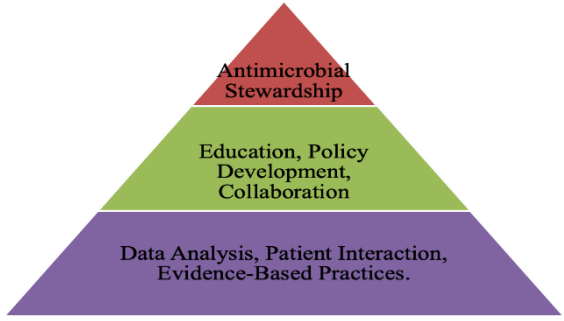

Figure 1. Clinical pharmacists' roles.

Another fundamental and integral part is education to the clinical pharmacist when deploying and executing the ASP. These programs focus on maximizing the benefit to patients through improved outcomes and minimizing side effects associated with antimicrobial use, such as toxicity and the selection of resistant organisms (Falcione & Meyer, 2014). Falcione and Meyer state that through their participation in ASPs, pharmacists can facilitate improved clinical outcomes and the judicious use of healthcare resources (Falcione & Meyer, 2014). Collaborative practices are supported by the mandate that pharmacists, while working together with physicians and other health care professionals, closely monitor antibiotic use and intervene in the treatment when there is a need for revision (Fanella & Walus, 2014; Chahine et al., 2014). This teamwork is what facilitates antibiotics therapies to be both safe and effective and, by proxy, reduce microbial resistance. In addition, the data indicate that the involvement of clinical pharmacists in health care systems is associated with better outcomes for patients and decreased rates of antimicrobial resistance. To illustrate, Alomi et al. reported a very high percentage of hospitals adopting ASPs in Saudi Arabia and indicated the increasing role of pharmacists in this very

important area (Alomi et al., 2018). Similarly, it has been evident that the quality of antimicrobial dispensing can be improved by pharmacists. However, further education and awareness initiatives are still required for the betterment of such practices (Souza et al., 2022; Belachew et al., 2021).

Figure 2. Antimicrobial Stewardship Implementation.

First, AMR is considered one of the major threats to public health. The World Health Organization (WHO) and other health agencies have termed it a global crisis Aslam et al. (2018). The inappropriate use of antimicrobials in human medicine or agriculture hastens the emergence of resistant strains that cause infections increasingly challenging to treat (D'Arcy et al., 2021). For instance, improper use of antibiotics in animals has been linked to the appearance of resistant pathogens that may be transferred to humans through food (Ibrahim et al., 2019). This zoonotic transmission highlights the requirement of a "One Health" approach integrating strategies involving human, animal, and environmental health in order to effectively counter the challenge of AMR in all its manifestations (Törneke et al., 2015).

This also has huge economic effects. Infections from multidrug-resistant organisms lead to protracted stays in the hospital setting, increased costs of treatment, and a higher rate of mortality than otherwise expected (Kim & Park, 2018). A study projected that AMR would cause about 10 million deaths each year by 2050 if the current trend persisted, thus calling for an urgent need for effective antimicrobial stewardship and public health interventions (Lopez, 2022). The burden of AMR not only burdens individual patients but also strains the healthcare systems, thus there is a need for policies that enhance the rational use of antimicrobials (Kumar et al., 2021; ANTON, 2024). The epidemiology of AMR is also concerning, as it varies significantly across regions and is influenced by local prescribing practices and healthcare infrastructure. For example, studies in various African countries have shown high rates of resistance among common pathogens, which complicates treatment protocols and public health responses (Tadesse et al., 2017). Furthermore, there are the multidrug-resistant pathogens, including those producing ESBLs, that represent a significant threat to current standard treatments since they neutralize these treatments (Karthikeyan et al., 2010). In AMR, because the globe is one big market for its strains, the spreading of resistant strains across borders makes things very difficult for public health efforts (Kang & Song, 2013).

2. The Role of Clinical Pharmacy in Combating Microbial Resistance

Among the major roles of clinical pharmacists in ASPs is education of healthcare providers and patients on the appropriate use of antibiotics. This educational role is very important because it has been shown that interventions led by pharmacists do significantly improve prescribing

practices and clinical outcomes (Craddock et al., 2020; Charani et al., 2019). For instance, education of prescribers and patients may reduce inappropriate antibiotic prescription rates, mainly in outpatient settings where abuse is widespread (Craddock et al., 2020; Charani et al., 2019). Pharmacists may be able to promote a culture of responsible antibiotic use within health care facilities by making individuals more aware of antibiotic resistance and the need for judicious prescribing. Apart from education, clinical pharmacists also participate directly in the care process of antibiotic therapy management. This includes the evaluation and rationalization of the antibiotics ordered by following the present guidelines with patient-specific factors, such as renal function and the potential drug interaction that Appaneal et al. (2018) and Broom et al. (2015) suggest.

Pharmacists are frequently included in multidisciplinary rounds; pharmacists will provide timely decision support to ensure antibiotic therapy is appropriately adjusted for an individual's need (Baubie et al., 2019). Their pharmacotherapy knowledge allows them to identify opportunities for de-escalation, such as switching from broad-spectrum to narrower-spectrum antibiotics, thereby reducing the development of resistance (Halcomb & Johnson, 2022; Brower et al., 2020). Further, clinical pharmacists develop and execute institutional policies and guidelines in respect to the use of antibiotics. They are highly crucial in formulating surgical prophylaxis protocols, empirical treatment of common infections, and tracking adherence to such protocols (Abubakar et al., 2019; Zhou et al., 2016). Through data on antibiotic use and resistance patterns, the pharmacists play a role in determining what trends and areas need improvement with such information guiding the overall strategy of the ASP. Such an approach pushes the stewardship efforts to be responsive to the needs of the health care setting and the patients served by it (Díaz-Madriz et al., 2020; Xu et al., 2022).

Table 1: Key roles of clinical pharmacists in combating AMR.

Role	Description	References
Education	Training healthcare providers and patients on appropriate antibiotic use.	(Sakeena et al., 2018)
Antimicrobial Stewardship	Implementing ASPs to optimize antibiotic prescribing and reduce resistance.	(Falcione & Meyer, 2014)
Policy Development	Formulating guidelines for antibiotic use in clinical and public health settings.	(Abubakar et al., 2019)
Data Analysis	Monitoring prescribing trends and resistance patterns to inform interventions.	(Tang et al., 2020)

The clinical pharmacist's role with ASPs involves collaboration. They team up with physicians, nurses, and other health care providers to encourage the adoption of a collaborative approach in antibiotic stewardship (Broom et al., 2015; Charani et al., 2019). This will be able to address multifactorial aspects of antibiotic prescribing and resistance in the design of effective interventions, integrating all the different perspectives and expertise together (Sakeena et al., 2018; Amawi et al., 2021). Pharmacists can also be champions in stewardship initiatives advocating best practices and helping work over the barriers to implementations within their institutions (Appaneal et al., 2018; Dionne et al., 2022). One of the main ways through which

clinical pharmacists contribute to antibiotic stewardship is by being directly involved in developing and implementing ASPs that aim at optimizing antibiotic prescribing and reducing the emergence of resistant strains. They should normally be an important member of the ASP team, who evaluates the use of antibiotic practices, monitors adherence to guidelines, and makes appropriate recommendations on changing therapy based on clinical evidence (Khan et al., 2016; Buckel et al., 2016). For instance, it has been documented that the engagement of pharmacists in academic detailing and adherence to guidelines reduces the use of broad-spectrum antibiotics significantly, which subsequently reduces their resistance (Buckel et al., 2016; Res et al., 2016).

In addition to their inclusion in ASPs, the clinical pharmacists play a crucial role educating healthcare providers and patients of the proper use of an antibiotic. They train and arm the prescribers to remove misconceptions regarding antibiotic therapy and adherence to the guidelines (Fleming-Dutra et al., 2018; Tang et al., 2020). In addition, the pharmacists engage with patients educating them on what the medicines are for and why a course needs to be finished and what to expect from inappropriate use (Torres et al., 2020). This education aspect is significant in ensuring the patient takes part in their care, and therefore it helps prevent the possibilities of non-adherence or abuse.

The clinical pharmacist provides good communication between health practitioners. Such an activity aids the proper usage of antibiotics, an action proven to improve significantly by better pharmacist-provider communication (Khan et al., 2016; Seaton et al., 2022). Active participation within rounds and discussions through multidisciplinary approaches gives direct feed on the selection of choice of antibiotics, alternatives, or de-escalation as proper (Fleuren et al., 2019). This helps improve outcomes concerning the patient and fosters a responsible culture towards mutual accountability among health team workers. Moreover, clinical pharmacists are involved in data analysis. This is to monitor prescribing behavior of antibiotics and tracking trends of resistance. They can spot potential areas for improvement by conducting audits and analyzing prescription data that could be used to create targeted interventions (Tang et al., 2020; Hayes et al., 2023). It is possible through this data-driven approach for them to continually evaluate the success of the stewardship program while keeping strategies current and relevant to the use of antibiotics (Xu et al., 2022; Staub et al., 2019).

3. Microbial Resistance: A Global Public Health Threat

The overuse of antibiotics is one of the main drivers of AMR in both human medicine and agriculture. Prescribing of antibiotics, either because of uncertainty in diagnosis or patient pressure, results in an overexposure of bacteria to these drugs and favors the development of resistant strains Silva et al. (2022) Schwartz et al., 2020). Inappropriate prescribing has been widely studied, showing that such inappropriate prescribing occurs frequently in the primary care sector, in which physicians have a pressure to prescribe antibiotics even if there is no clinical need to do so (Schwartz et al., 2020; Marsh et al., 2023). Such a situation has been amplified more in low-and middle-income countries due to the availability of less-controlled access to antibiotics (Lobie et al., 2021; Nashwan, 2024). In addition to the direct effect on human health, another significant area of contribution to AMR has been agriculture, by virtue of the use of

antibiotics. Antibiotics are primarily used in the agricultural sector to not only treat animals when they fall sick but also as growth promoters in the production of livestock (Noyes et al., 2021; Solís-Cruz et al., 2020). Such practice leads to selective pressure on the bacterial populations and aids in the development of resistant strains, which can be passed on to humans through the food chain (Noyes et al., 2021; Keely et al., 2022). This is then made worse by the fact that this has an environmental effect: agricultural runoff laced with antibiotics leads to source contamination and the distribution of resistance genes among the microbial community (Pärnänen et al., 2019; Port et al., 2012).

Environmental dissemination of antibiotic resistance genes is considered important. Resistant bacteria and genes can survive within environmental reservoirs, including in wastewater treatment plants. The freed resistant bacteria and genes will keep on the cycle of resistance (Pärnänen et al., 2019; Mbanga et al., 2021; Akebe et al., 2022). For example, there is enough evidence in many studies demonstrating that the patterns of antibiotic resistance in wastewater treatment plants are the same as in clinical settings-this therefore indicates that there is directly a relation between environmental resistance and clinical resistance (Pärnänen et al., 2019). The presence of resistant bacteria in natural water bodies poses not just a risk to public health but also to ecosystems since these can transfer resistance genes to other pathogens (Port et al., 2012; Akebe et al., 2022).

Socioeconomic factors are also a major contributing factor in the spread of AMR. In most regions, especially developing nations, poor sanitation and healthcare infrastructures contribute to the spreading of resistant organisms (Nashwan, 2024; Mbanga et al., 2021). This makes the problem worsen since public health systems are not given the same development as seen with rapid urbanization and industrialization, resulting in increased exposure of humans to antibiotics and utilization in animals as well (Akebe et al., 2022; Ahmad, 2024). Public education and awareness have been a scarce resource, fueling continued misuse and overuse of antibiotics (Anderson, 2018). Finally, climate change is also envisioned to be a potential mediator in the development of AMR. Changes in temperature and environment also may influence the survival of spread of resistant bacteria in addition to the effectiveness of the antibiotics (Pärnänen et al., 2019; Nashwan, 2024). In this regard, an increasing number of bacterial strains showed increased resistance at increasing temperature levels, which puts into focus the complex interaction among the environmental factors and microbiologic resistance (Pärnänen et al., 2019).

The primary contributing factor of AMR in developing countries is the extensive misuse and overuse of antibiotics. In most LMICs, antibiotics are usually dispensed without prescriptions, resulting in self-medication and misuse Hazaa et al. (2020) Zaw et al., 2021). For example, in Egypt, a very lenient policy on prescription of antibiotics is related to very high resistance rates (Dooling et al., 2014). On the contrary, in developed countries, more stringent rules and standards are followed for the administration of antibiotics, but this doesn't prevent misuse completely (DeBaun et al., 2021). It implies there will be a higher prevalence of the multi-drug-resistant pathogenic flora across developing countries, as clearly presented by the strains of the bacterium Salmonella Typhi in Kenya Mengo et al. (2010), and several pathogens as highlighted in Bangladesh (Ahmed et al., 2019). Health infrastructures also form a prominent area of disparity between developed and developing nations. In many developing countries, laboratory

facilities for performing antibiotic susceptibility testing, healthcare access is limited, and infection control measures are lacking in several areas (Ahmed et al., 2019; Hassan, 2021). This limits the monitoring as well as the response abilities of AMR. Developed countries generally have stronger healthcare systems that can carry out full surveillance and stewardship activities to counter AMR (DeBaun et al., 2021; Dooling et al., 2014).

Socioeconomic factors make the issue worse in developing countries. Advanced levels of poverty, undernutrition, and chronic health issues do not help in reducing but instead increase the prevalence of infection and the need for antibiotics (Ahmed et al., 2019; Hassan, 2021). This is, however, complicated by how the newer, more powerful antibiotics are not available locally or are too expensive and cannot be afforded by such populations in LMICs (Ahmed et al., 2019; Hassan, 2021). While the AMR issue exists in developed countries, the overall healthcare system is much better at managing infections and providing access to advanced treatments. Public awareness and education on the use of antibiotics and resistance are usually absent in developing countries. The individual may not know why an antibiotic course should be completed or what risks are involved in its misuse, which contributes to increased resistance (Ahmad et al., 2015; Waseem et al., 2019). The practice of using antibiotics responsibly was well promoted in developed countries for much longer periods of public health campaigns, although there remains an area that is still quite lacking (DeBaun et al., 2021; Dooling et al., 2014).

4. Public Health Interventions to Combat Microbial Resistance

The global response to antimicrobial resistance has been structured around a number of key strategies and frameworks, the World Health Organization's Global Action Plan on Antimicrobial Resistance being a foundational framework. This is the WHO Global Action Plan against antimicrobial resistance adopted by the World Health Assembly in 2015. This integrates the plan of action on AMR through collective action with a multi-layered, multi-stakeholder response and gives rise to underpinning "One Health" approaches of human, animal, and environmental health as postulated by Bloom et al., 2017, and Sumpradit et al., 2021. The WHO Global Action Plan aims to enhance surveillance and research on the consumption and resistance patterns of antibiotics. Effective monitoring systems need to be developed to trace antibiotic consumption and the incidence of resistant strains, providing important information on targeted interventions (Barchitta et al., 2019; Mupfunya et al., 2020). For example, local monitoring systems such as that developed in Sicily, Italy have been put in place to trace the antibiotic consumption and evolution of resistance.

Data obtained has thereafter been used as a resource in designing strategies for dealing with AMR (Barchitta et al., 2019). Other types of approaches that should be incorporated in the data-driven stream are needed to better understand resistance dynamics for proper policy decisions. Altogether, the WHO policy says there is a need to encourage antibiotic stewardship programs for their effective use in human medicine and veterinary medicine. Through these programs, it has been seen that the number of prescriptions issued unnecessarily has to be brought down to as much an extent as possible. Where antibiotics will be used strictly, and the selective pressures that fuel resistance development have to be minimized (Bloom et al., 2017; Sumpradit et al.,

2021). Countries are encouraged to have national action plans along the WHO framework and focus education, regulation, and implementation of guidelines concerning antibiotic use (Sumpradit et al., 2021).

Table 2: Public Health Interventions Addressing AMR.

Intervention	Impact	References
Vaccination Programs	Reduce infections and subsequent antibiotic demand.	(Wantuch & Avci, 2018)
Infection Control Measures	Prevent the spread of resistant pathogens in healthcare settings.	(Shaaban, 2024)
Public Awareness Campaigns	Educate the public on responsible antibiotic use.	(Anderson, 2018)
Surveillance Systems	Track antibiotic consumption and resistance trends.	(Barchitta et al., 2019)

International cooperation is also enhanced in the fight against AMR. The WHO urges countries to partner each other in data sharing, resources, and best practices since AMR is a global problem that transcends borders (Eriksen et al., 2021). Other initiatives like the Global Health Security Agenda and the UN Sustainable Development Goals include AMR as one of the critical components; hence, it calls for a global response (Cars et al., 2021). In addition, the One Health approach is increasingly recognized to be key in addressing AMR. Such an approach recognizes that human, animal, and environmental health are interconnected; they advocate for coordination and cooperation among these sectors to curb resistance dissemination (Mouiche et al., 2019). Such as regulations on the antibiotic use in agriculture and with public health initiatives, an overall burden of AMR varies (Landers et al., 2012).

4.1. Vaccination Programs

Vaccination is an important preventive measure to prevent infections caused by antibiotic-resistant bacteria because it reduces the incidence of all infectious diseases in a population and ultimately contributes to a decrease in antibiotic demand. For example, pneumococcal conjugate vaccines have been proven to reduce the number of invasive pneumococcal disease, thereby reducing the number of prescriptions on antibiotics that would contribute to pressure causing resistance Wantuch & Avci (2018) Clift & Salisbury, 2017). A systematic review found that vaccination can be very effective in reducing the carriage of antibiotic-resistant bacteria, which supports the concept that vaccines can be used to control AMR (Wang et al., 2021). In addition, vaccination programs can provide herd immunity, protecting those not vaccinated and decreasing the total spread of resistant pathogens in communities (Wang et al., 2021). This indirect benefit is of paramount importance in vulnerable populations, as severe infections have a higher risk. With vaccination programs decreasing the prevalence of infections, a substantial reduction in antibiotic use will be obtained, and this is one of the important strategies in the fight against resistant strains (Clift & Salisbury, 2017; Doherty et al., 2020).

4.2. Infection Control Measures

Infection control measures have a similar role in countering microbial resistance. Some of these practices are hand hygiene, use of PPEs, sterilization of equipment, and isolation of infected patients. Good infection control will prevent the spread of nosocomial resistant organisms and thus minimize the cases of HAIs (Tang, 2017). For instance, strict infection control practices in

hospitals are associated with lower levels of multidrug-resistant organisms; this indicates that such practices are effective in controlling the development of resistance (Shaaban, 2024). Furthermore, infection control practices play a major role in the control of outbreaks of resistant infections. The strict protocols help contain the outbreaks and prevent further transmission in settings where antibiotic-resistant strains are prevalent (Shaaban, 2024).

5. Healthcare Policy Development and Implementation

5.1. Global Action Plan on AMR

The WHO's global action plan, adopted back in 2015 consists of five strategic objectives aimed at improving awareness and understanding related to AMR, along with strengthening surveillance and products research, reducing the incidents of infection, optimizing antimicrobial agents use, as well as ensuring sustainable investments in countering AMR (Kariuki et al., 2022; Munkholm & Rubin, 2020). This combined framework should be prompted to contain such objectives at the country-level of countries, thereby triggering a converged worldwide response towards AMR (Kariuki et al., 2022; Munkholm & Rubin, 2020). The policy caters for the approach under the \"One Health" by taking into consideration human health, animal health and environmental health together about battling the menace of AMR ("undefined", 2023).

5.2. Country Action Plan

As a result of the Global Action Plan by WHO, various countries have built their personal NAPs. The NAP-AMR in India was developed with the WHO framework to control the environmental spread of AMR and improved surveillance systems (Ranjalkar & Chandy, 2019). One Health was utilized by the Antimicrobial Resistance Technical Working Group in Nigeria in the fight against AMR, engaging all stakeholders involved (Onah, 2023). Such national plans usually entail the interventions for strengthening antimicrobial stewardship, infection control and prevention practices, and public awareness on AMR (Ranjalkar & Chandy, 2019; Onah, 2023).

5.3. Regional Activities

Besides the national efforts, regional activities also play an important role in trying to address the problem of AMR. In the case, a European Strategic Action Plan on Antibiotic Resistance was established to support EU member states in matters related to the policy implementation to help curb the spread of AMR; it provided suggestions on surveillance, stewardship, and public health interventions (Gulumbe et al., 2022). Even Sub-Saharan African countries are being encouraged to begin preparing their AMR readiness plans, which, among other things, focus on antimicrobial stewardship. Such regional frameworks offer the possibility of collaboration and learning from each other for countries with similar problems regarding AMR (Elton et al., 2020).

5.4. Research and surveillance

Surveillance is crucial in the monitoring of antibiotic consumption and resistance patterns. The WHO has laid emphasis on the development of strong surveillance mechanisms to be used in informing policy decisions and guiding interventions (Barchitta et al., 2019). It would inspire

countries to provide rates of antibiotic use and resistance data, which allows for tracking and appropriate measures in tackling the AMR phenomenon (Klein et al., 2018). For example, surveillance of antibiotic usage in regions such as Sicily has led to the detection of some of the effective practices against AMR (Barchitta et al., 2019).

5.5. Improving Clinical Competencies and Practice:

Evidence-based clinical practice is based on a set of principles, but such a practice has recommended never-ending education and training sessions for pharmacists. According to some research evidence-based medicine programs have improved the clinical competencies of the practitioners, and confidence about well-informed decisions of providing patient care (Auta et al., 2016). Farha et al, 2014). For example, clinical postgraduate pharmacy practice training programs in England have been known to be essential to providing specialized skills that ensure a pharmacist can effectively contribute to patient care and management of medication. Such a practice may inform policy decisions on the education and certification of pharmacists to ensure them well-prepared for an ever-changing healthcare system (Auta et al., 2016).

5.6. Promoting Antimicrobial Stewardship

Clinical pharmacy practices that are evidence-based are highly significant in contributing to ASPs. The evidence-based antibiotic regimen, including designing and implementing, patient monitoring, and evaluating the outcomes of treatment, are crucial activities for pharmacists (Hidayat et al., 2012). Studies have shown that clinical pharmacists involved in critical care settings led to better outcomes and decreased healthcare costs. This evidence would guide policymakers in setting up frameworks that integrate clinical pharmacy services into ASPs in the hope of decreasing AMR incidence (Hasan et al., 2019).

Table 3: Economic and Epidemiological Impacts of AMR.

Aspect	Description	References
Healthcare Costs	Increased costs due to prolonged hospital stays and complex treatments.	(Kim & Park, 2018)
Mortality Rates	Higher death rates from multidrug-resistant infections.	(Lopez, 2022)
Global Burden	Projected 10 million deaths annually by 2050 if trends persist.	(Lopez, 2022)

5.7. Identifying barriers and facilitators

The findings of the barriers and facilitators of clinical pharmacy practice may be helpful for policy makers. For example, staff numbers, resources, and institutional support have been known to be critical enablers of effective clinical pharmacy services (Auta et al., 2015; Mekonnen et al., 2018). Such knowledge would allow policymakers to develop targeted interventions for specific challenges faced by pharmacists in various health care settings, which would ultimately strengthen the overall effectiveness of pharmacy services.

5.8. Promoting Rational Medication Use:

Other clinical pharmacy-based evidence practices aim at ensuring there is rational medication use-the very key to the fight against AMR. The pharmacists could thus reduce prescriptions with no apparent cause, and this would lead to better outcomes for patients (Hasan et al., 2021).

Policymakers can work from this evidence to create and come up with regulations or guidelines that support rational prescribing as part of combating AMR.

5.9. Informing Public Health Initiatives:

Integrating evidence-based clinical pharmacy practices into public health programs helps in reducing AMR in related programs. For instance, through the community pharmacies, patients will be informed on the safe use of antibiotics and completing a prescription course in time Saleh et al., 2021; Al-Quteimat & Amer, 2016. Evidence of this impact on public health about the effects of community pharmacy interventions can be used as policy in extending the pharmacist's role in health promotion and disease prevention.

Assistance in Research and Development:

Another research and development drive is evidence-based clinical pharmacy practice. Pharmacist support for new policy formulations helps in enabling research work and improving drug management of a patient. A collaboration setting may eventually lead to groundbreaking solutions that improve patient outcomes better (Obaid et al., 2021; Alefishat et al., 2022).

6. Integrating Clinical Pharmacy into Public Health Policies

6.1. Implementation of Antimicrobial Stewardship Programs:

Clinical pharmacists must be the core actors in healthcare antimicrobial stewardship programs. Their experience in pharmacotherapy allows them to assess antibiotic prescriptions, suggest alternative treatments, and monitor patients' responses to the suggested alternatives Zahawi et al. (2021) Abu-Gharbieh et al., 2010). Numerous studies have established that when clinical pharmacists are part of ASPs, they enhance the use of antibiotics, thus reducing antimicrobial resistance rates Nørgaard & Sporrong, 2019). This can be supported through policies and also inclusion of clinical pharmacists in the ASPs by ensuring such pharmacists receive appropriate provisions, which would then help make them actively participate in their involvement.

6.2. Improving collaborative practice

The presence of clinical pharmacists with all the other health care providers improves the optimum care for patients. Studies have indicated that health care providers recognize the importance of clinical pharmacists in improving medication management and patient outcomes (Abu-Gharbieh et al., 2010; Alomi et al., 2020). The involvement of multidisciplinary teams that comprise clinical pharmacists may be useful in conducting comprehensive patient assessments, which can, subsequently lead to enhanced identification and resolution of medication-related problems (Mekonnen et al., 2013). Interprofessional collaboration policies can enhance the communication and improve clinical pharmacy services.

6.3. Implementing Ward-Based Clinical Pharmacy Services:

Most probably, clinical pharmacy services offered from within the ward of the hospital would benefit the patients more than in any other way. In a ward-based clinical pharmacy setting,

pharmacists can review medications, make real-time recommendations, and participate in rounds with health care teams (Mekonnen et al., 2013; Jagpal et al., 2019). This has been proven to enhance drug safety and efficacy, especially in higher risk patient populations (Mekonnen et al., 2013). Healthcare systems should include policies that support the inpatient clinical pharmacist deployment in patient care for maximum impact.

6.4. Policy for Promotion of Education and Training

Clinical pharmacists must continually expand their expertise in evidence-based practices for appropriate contribution within the health system. With a focus on antimicrobial stewardship, medication management, and patient counseling, a pharmacist will gain experience to remain competent (Lanier et al., 2019; Hermansyah et al., 2018). Funding such educational programs with the competency of a pharmacist to contribute to addressing microbial resistance and quality patient care is paramount for the policy maker.

6.5. Promotion of public health programs

Clinical pharmacists have become instrumental in public health initiatives targeted towards educating the public regarding proper antibiotic use and possible antibiotic resistance. A community pharmacy setting provides a point where the pharmacist may make direct contact with patients, counseling and educating them on appropriate usage of drugs (Siltrakool et al., 2021; Dreischulte et al., 2022).

The integration of technology and data analytics in clinical pharmacy practice will enhance monitoring of antibiotic use and resistance patterns. Clinical pharmacists use electronic health records and decision-support systems to analyze trends and therefore support clinical decision-making: Yannuzzi et al. 2015; El-Ibiary et al., 2017.

6.6. Advocacy for Policy Changes

They can also advocate for policy change to support expansion in their roles in the health sector. This is through providing legislation that will pave the way for the engagement of pharmacists in direct patient care, medication prescription, and billing of clinical services (Lanier et al., 2019; Aziz et al., 2019). Therefore, the engagement in policy dialogue and interaction with stakeholders helps to bring about an enabling regulatory environment conducive to the appreciation and expansion of clinical pharmacy service contributions.

7. Future Directions and Research Priorities

7.1. Development of Good Communication and Colloboration:

Interdisciplinary research enhances good communication as well as collaboration of experts from health care including health professionals like medicine, pharmacy, nursing, and the public. It is understood that positive inter-professional communication increases the efficacy and successful outcome in patient care services Verhaegh et al. (2017). Thus, building inter-professional collaboration and respect for a culture may eliminate silos in the whole health system and then lead to a more integrative and patient-centered approach Andersson et al., (2011).

7.2. Complex Health Challenges' Management

Complexity of the health care problems like AMR needs input from different disciplines, and, thus, interdisciplinary research. The integration of ideas from different disciplines, such as microbiology, pharmacology, sociology, and public health allows for a better and more holistic analysis of the problems related to health. An example is knowledge about the social determinants that might lead to the formulation of policies geared towards reducing AMR, such as improving access to health care and awareness on proper use of antibiotics (Robinson et al., 2022).

7.3. Informed Evidence-Based Policy Development

Interdisciplinary research gives clear indications that could inform health policy. An example is how a systematic review and meta-analysis of an interdisciplinary approach, like the Cochrane Collaboration, as indicated by Cipriani et al. (2011), establishes evidence regarding intervention efficiency. Policymakers will then use such evidence to make informed decisions about improving outcomes for patients and healthcare service provision generally. Moreover, interdisciplinary research identifies areas of current knowledge gaps and where future research is required. These can be used as an outline for future research agendas (Schors, 2023).

7.4. Creative Solutions

This may lead to new ways of addressing health issues since the link between the researchers from other disciplines. For example, interdisciplinary teams may devise new care models such as using technology telehealth that may make healthcare services accessible (Abdul, 2024). Interdisciplinary research may involve different expertise and may, therefore, be creative and effective health policies towards emerging health issues.

7.5. Science Implementation Enabling

Implementation science is the process through which one knows how well research can be translated to practice. It can take the form of interdisciplinary teams that review barriers and facilitators of evidence-based interventions and develop approaches to strengthen the uptake of such effective practices in healthcare settings, hence ensuring that policies formed are evidence-based and practical, hence sustainable in real-world scenarios (Tumilowicz et al., 2019).

7.6. Stakeholder Engagement:

Sometimes, more than one stakeholder in the research process may be involved, like patients, healthcare providers, or policymakers. It is how all the concerns and needs of the parties involved are considered in the policy-making process (Nel et al., 2023).

7.7. Facilitating Continuous Learning and Adaptation:

Health care policies must be dynamic and change with new evidence or a shift in circumstances. Interdisciplinary research promotes a learning culture, always adapting and changing, which enables health care systems to be sensitive to issues that are surfacing (Bréton et al., 2013). Continuous collaboration and knowledge exchange between disciplines might make health care policies current and updated with the best evidence and practices.

8. Conclusion

To deal with the increasing threat of antimicrobial resistance, a robust public health response along with innovative policy frameworks must have an integrated and multidimensional approach. The role of clinical pharmacists is crucial in the stewardship of antimicrobials by providing critical education, data-driven analysis, and customized guidelines for optimizing antibiotic use. They contribute to improved patient outcomes, lower rates of resistance, and sustainable health practices. Global and national action plans are, therefore, a must, based on the "One Health" approach. They must comprise interdisciplinary cooperation, technological integration for real-time surveillance, and focused public awareness efforts leading to behavioral change. Infrastructure in health services and sectoral partnerships will be decisive in this regard. In conclusion, the next steps going forward should be to arm the clinical pharmacists, putting within their reach the advancement in the training, adequate resource for doing the job, and taking on wider roles in policymaking and policy implementation. United effort, through exploitation of unique capacities of clinical pharmacists, creates a healthy resilient system robust enough at dealing with AMR even while keeping alive useful antibiotic therapies.

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Author contributions

The corresponding author assisted the first author in drafting the original manuscript. Final permission is granted to each author before the paper is submitted to a journal for publication. Every co-author took part in the editing of the manuscript, the gathering of literature, and the construction of tables and figures.

Conflict of Interest

The authors declare no conflict of interest, financial or otherwise.

Ethical Approval

Not Applicable

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