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Antimicrobial Resistance: A Cross-Disciplinary Approach in Pharmacy, Laboratory Testing, and Imaging: A Review article

Amirah Essa Hussain Jafari[1], Shaima Abdullah Ibrahim Hamzi[2], Zahra Hassan Alanki[3], Fatimah Jassim Alsanawi[4], Doha Abdulghani Yossef Aleid[5], Zainab Muslim Alshatti[6], Anwar Saran Aljameeli[7], Wadiah Yousef Al Dhamen[8]

1. *Ph_amirah@hotmail.com Pharmacist in Al-Khafji General Hospital Khobar*
2. *Pharmd.shaima@gmail.com Pharmacist in king Fahad hospital al baha Jazan*
3. *zalanki190@gmail.com Radiology technician in Al-Khafji General Hospital Saihat*
4. *Fatimah.biology@gmail.com Phlebotomist in Al-Khafji General Hospital Khobar*
5. *daaleid@moh.gov.sa Lab technician in Al-Khafji General Hospital Saihat*
6. *Alshatti_Z@Outlook.com Pharmacy technician in Al Khafji General Hospital Al Qatif*
7. *asaljameeli@moh.gov.sa Pharmacy technician in Al Khafji General Hospital Al Khafji*
8. *Ana_leek_j@hotmail.com Radiology technologist in aljaffer general hospital Al Qatif*

Abstract

Introduction: Antimicrobial resistance (AMR) represents an international public health threat; defined as, the ability of microorganisms, including bacteria, fungu, virus, and parasites to resist antimicrobial treatments that were earlier effective against them. Effective action against AMR requires extensive antiviral, antimicrobial and antibiotics approach that involves cross cooperation of pharmacists, laboratory technicians and radiographers in delivering diagnosis, treatment and management solutions.

Aim of work: To explore the critical roles of pharmacy, laboratory testing, and medical imaging in the management of antimicrobial resistance (AMR).

Methods: The keywords" Antimicrobial, Resistance, Cross-Disciplinary, Approach, Pharmacy, Laboratory Testing, and Imaging" were used to conduct a thorough literature search in the MEDLINE database to find relevant publications published between 2016 and 2024. Using the proper search terms, Google Scholar was utilized to find and access pertinent scientific publications. Various inclusion criteria were used to choose which articles to select.

Results: The research included in this study was published from 2016 to 2024. The research included a discussion segment that was broken into many specific elements. Topics covered include The Role of Pharmacy in Combating AMR, The Role of Laboratory Testing in AMR Management and The Role of Imaging in AMR Management.

Conclusion: The vital contributions of pharmacists in the fight against AMR include stewardship programs, therapy optimization, education, infection prevention, policy advocacy, and research. Laboratory confirmation is integral in managing AMR, adding data and knowledge input for speedy identification of disease. Imaging is also essential for quick diagnosis of resistant infections, feedback in targeting therapy and the development of resistance mechanisms. Thus, the adoption and application of these technologies in clinical settings have the potential to enhance patient care and mitigate AMR's global risks. A collaborative multispecialty approach involving pharmacists, laboratory personnel, and imaging modalities is required for improved detection, management, and outcome of resistant infections to ensure optimal patient and public health.

Keywords: ***Antimicrobial, Resistance, Cross-Disciplinary, Approach, Pharmacy, Laboratory Testing, and Imaging***

Introduction

Antimicrobial resistance or AMR is a major global health threat defined as the ability of pathogens – bacteria, fungi, viruses, and parasites – to stop responding to antimicrobial treatments that previously controlled them [1]. Combating AMR requires an all-encompassing, interprofessional outline including pharmacy, laboratory tests, and imaging that may improve diagnosis, treatment plans, and the overall management of the condition [2].

Through medication therapy management, pharmacists play an essential role in combating and controlling AMR. Some of their roles include promoting correct use of antimicrobial drugs, determining correct dosing schedules and informing patients on correct utilization of medications. Through engagement in antimicrobial stewardship initiatives, pharmacists contribute to the prudent use of antibiotics hence prevention of the resistance [3].

Stewardship makes use of laboratory testing results that are accurate and timely in order to determine the presence of resistant pathogens and subsequently come up with the right treatment plan. Some examples include the Antimicrobial Resistance Laboratory Network (ARLN), which works with laboratories across the country to spread, identify, and track new antimicrobial-resistant threats. These include susceptibility testing of Aspergillus fumigatus, and Candida species including C. auris to azoles to determine resistance trends for public health management [4].

Subsequently, new rapid diagnostic techniques have also helped to improve the identification of AMR. For instance, stimulated Raman scattering imaging enables the quick accomplishment of antimicrobial susceptibility testing by assessing metabolic activity of individual bacteria and getting the results in several hours [5]. Such innovations help clinicians make decisions and hence enhance patient care, and decrease the spread of resistant strains.

Molecular imaging has been proved to be useful for assessment of antimicrobial pharmacokinetics in vivo. For instance, positron-emission tomography (PET) is a technique that uses drugs labeled with a radioactive tracer, to depict the concentration of the drug in the living body in real-time. It offers knowledge on the extent to which drugs reach affected sites which is imperative in fine-tuning genuine antimicrobial therapy and the invention of new approaches to treating infections [6].

The integration of specialties such as pharmacy, laboratory services, and imaging contributes to a multidisciplinary approach to managing AMR. Due to highly specific laboratory findings, along with other information on the patient's condition, pharmacists can optimize the antimicrobial treatment for maximizing its efficiency and minimizing the chance of resistance development. At the same time, imaging helps to obtain crucial data about drugs' behaviour in the body, which influence dosages and treatment periods [7]. Furthermore, laboratory professionals are also involved in patient care and appropriate use of antimicrobial agents since they give rise to timely information to the physicians and pharmacists. By being experts in one's clinical area, they are able to appropriately identify resistant pathogens and make relevant interventions [8].

The purpose of this review is to identify and explain the significant contributions of pharmacy, laboratory testing, and medical imaging in addressing AMR. Although the focus of these fields

varies, this review aims to discuss their individual roles and synergy to promote effective AS practices, increase diagnostic precision, strengthen therapeutic management, and advance public health approaches. Further, the review seeks to emphasize the role of technology, education, and research to enhance the understanding of effective measures for addressing the threat of AMR globally.

AIM OF WORK

To explore the critical roles of pharmacy, laboratory testing, and medical imaging in the management of antimicrobial resistance (AMR).

METHODS

Scientific research in this review was obtained through scientific websites (Google Scholar and Pubmed) using various keywords (Antimicrobial, Resistance, Cross-Disciplinary, Approach, Pharmacy, Laboratory Testing, and Imaging) to get all possible articles related to the current subject. The articles were chosen based on a set of criteria. First, each article's main titles and abstracts were reviewed, and then we excluded duplicate articles, non-full text articles, irrelevant articles, and case reports. The publications examined in this review were published between 2016 and 2024.

RESULTS

The current study included research on the critical roles of pharmacy, laboratory testing, and medical imaging in the management of antimicrobial resistance (AMR). The publications considered were published throughout the timeframe of 2016 to 2024. Hence, the review was organized in the discussion section according to several topics, such as The Role of Pharmacy in Combating AMR, The Role of Laboratory Testing in AMR Management and The Role of Imaging in AMR Management

DISCUSSION

AMR can be defined as process through which microorganisms including bacteria, viruses, fungi and parasites develop, one way or the other, ways and means of behaving as if they are not affected by antimicrobial agents [9]. This resistance makes standard treatments to be of no achievement, the infections to be chronic, and it is easier for the virus to spread to other people. The World Health Organisation has recognised AMR as one of the top ten global public health threats to humanity [10]. Key causes of development of AMR include; oversupply and improper usage of antibiotics, weak infection control measures, and less expenditure on new antimicrobial agents.

The Role of Pharmacy in Combating AMR

1. Antimicrobial Stewardship Programs (ASPs)

Pharmacists play a significant role in the establishment and application of ASPs, initiatives that aim at enhancing the utilization of antimicrobials while minimizing resistance. Some of these duties in ASPs include encouraging the appropriate use of antimicrobial agents, curbing the spread of infections, and providing the necessary information and knowledge to health professionals, patients, and the public. Some of the activities that may fall under this responsibility may include promoting interprofessional practice within the health system to ensure that the prophylactic, empirical, and therapeutic uses of antimicrobial agents lead to the best patients' outcomes [11].

2. Optimization of Antimicrobial Therapy

Pharmacists use their knowledge in the pharmacokinetic and pharmacodynamic principles with regard to staff in their identification of the correct antimicrobial, dosing regimen, route of administration, and duration of treatment. This individualised approach increases the effectiveness of the therapy at the same time reducing possible side effects and emergence of resistance. Data has found that pharmacists interventions in antimicrobial stewardship has decreased overall antibiotic utilization, costs, and days of therapy for different hospital wards, including general medical, surgical wards, and emergency medical department settings [12].

3. Education and Training

Pharmacists have an essential mandate a of raising awareness of the rational use of antimicrobials among healthcare providers and the community. Through sensitisation of AMR, pharmacists' use of IPR to discourage the overuse of antibiotics, which fuels resistance. Education and counseling of the patients as well as conducting awareness creation in the general population are among the ways through which this important information is passed. Consumers can be educated by pharmacists in how to utilise antibiotics correctly and assist other prescribers with antimicrobial use [13].

4. Infection Prevention and Control

According to evidence, pharmacists' roles in the framework of infection prevention and control were identified as the provision of vaccines, providing patients with information on infection prevention measures, and involvement in the formulation of standards on infection control. Their involvement also reduces the rates of infection and, in turn, lowers the chances of having to use antimicrobials and developing resistance to it. Community pharmacists can assist the patients to distinguish between myths and facts about immunizations and to gain knowledge on the topic of antibiotic resistance [14].

5. Policy Development and Advocacy

Policy makers and particularly pharmacists are involved in formulation of policies and policies championing for guidelines regarding use of Antimicrobials in combating AMR. They are members of professional organizations and sit on governmental advisory councils on issues to do with antimicrobial use and resistance. For example, the main objectives of the Society of Infectious diseases Pharmacists (SIDP) include the encouragement of proper utilization of antimicrobials and reduction of resistance [15].

6. Research and Development

Clinical pharmacists are involved in research on mechanisms of resistance, designing new antimicrobials and need assessment for stewardship. Their research is used to provide evidence for the interventions and clinical practices that are used to improve the existing strategy in addressing AMR. Employees of this profession are also active members of research and development, which are very useful in combating the advancement of AMR [14].

The Role of Laboratory Testing in AMR Management

1. Antimicrobial Susceptibility Testing (AST)

AST forms the basis in the ability to identify the effectiveness of individual antimicrobials against isolated organisms. It provides the bases for specific therapy while monitoring the growth response of microorganisms to antibiotics ST reduces antimicrobial misuse and thereby slows the development of resistance. Conventional techniques like disk diffusion and broth microdilution are still in practice, yet automation and other rapid phenotypic techniques are on the rise. Standard operating procedures for proficiency testing and with CLSI and EUCAST guidelines must be followed to ensure proper results of AST [16].

2. Rapid Diagnostic Techniques

Antimicrobial resistance screening has benefited greatly from the presence of rapid diagnostic tests (RDTs). PCR-based assays have not only facilitated to identify the resistance genes quickly but also made the start of optimum therapy faster. For instance, PCR-based technologies are essential in clinical laboratories for identification of drug resistance genes thereby cutting down on time needed for testing [17].

Furthermore, practices like matrix-assisted laser desorption/ionization-time of flight (MALDI-TOF) mass spectrometry make microbial identification faster and integrated molecular tests offer full-blown resistance data. The use of RDTs in clinical practice, especially in regard to AMR, has been linked with decreased mortality, shorter length of stays, and cost savings [17].

3. Diagnostic Stewardship

Diagnostic stewardship is a practice that entails order, timing, and use of laboratory tests that would help to improve the care of patients while at the same time addressing AMR. Thus, proper selection and timing of tests will assist the medical practitioners in proper management of antimicrobial therapy among the patients. This approach reduces the use of antibiotics and thereby curtails the ability of bacteria to develop resistance mechanisms. Diagnostic laboratories have an important role in the diagnostic stewardship process as they can inform clinicians about the available tests, explain and help with the correct interpretation of test results, and assist in the proper prescription of antimicrobials [18].

4. Surveillance and Epidemiology

Clinical and public health laboratories play significant roles in surveillance activities that focus on monitoring the occurrence and emergence of AMR. Based on susceptibility data, clinical laboratories are involved in the production of antibiograms for a given area of practice to guide empirical therapy. In this regard, membership in such networks like the ARLN is helpful for laboratories so that they can engage in developing strategies to address new threats of resistance in due course for the benefit of public health, which is keen on preventing spread of resistant organisms.

5. Quality Assurance and Proficiency Testing

The Striving for quality laboratory performance is critical in managing of AMR. Assessment of laboratories' performance by external checks through proficiency testing programs used on a frequent basis contributes to the minimization of errors when determining antimicrobial susceptibility. Conformity with quality assurance standards set down by such bodies as CLSI and EUCAST protects patients by eliminating wrong interpretations of susceptibility, which may result in the prescription of the wrong antimicrobial agents [16].

6. Integration with ASPs

Laboratories work in conjunction with ASPs to promote appropriate use of antimicrobials. This way, laboratories assist stewardship activities that call for the use of correct therapies and discourage use of antibiotics that are not necessarily necessary. This involvement also encompasses aspects such as providing guidelines for institutions and raising awareness among the HCWs as well as the surveillance of AMR resistance patterns [20].

7. Challenges and Future Directions

Nevertheless, there are still challenges in identification of AMR in laboratories today. New resistant mechanisms require frequent modifications to the testing strategies and the interpretation of results. However, utilisation of such technologies in resources scarce environments may be hampered by cost and physical infrastructure barriers. Areas of future work involve the production of affordable rapid diagnostic platforms applicable at the periphery of the healthcare system, and the incorporation of omics techniques for the determination of multilayered resistance phenotypes. It is therefore vital that this kind of research and investment continues in order to strengthen laboratory capacity and ensure that diagnostic capabilities forensically match the antimicrobial resistance threat tomorrow [21].

The Role of Imaging in AMR Management

1. Molecular Imaging in AMR Detection

Bacterial infections and antibiotic susceptibility with Molecular imaging in general and PET in particular have been characterized by using the current methodologies. For example, radiotracers derived from antibiotics including [11C]-trimethoprim([11C]-TMP), has been designed to have high affinity to bacterial enzymes. It has been established in various investigations that [11C]-TMP will localize itself in both MS and MR bacterial strains, therefore allowing visualization of infections irrespective of their responsive character. This capability enables the identification of resistance at an early stage, which can then guide appropriate therapeutic decisions [22].

2. High-Content Imaging and Machine Learning

The integration of high content imaging and machine learning algorithms form a robust technique for phenotyping bacterial responses to antimicrobials at the single cell level. Various high-throughput techniques have been invented to monitor bacterial susceptibility by studying shape-

shifting and metabolic alterations in response to antibiotics. It also applies various methods of antimicrobial susceptibility testing, which is quicker as compared with the conventional culture and susceptibility testing. In the same regards, machine learning algorithms trained on deep learning microscopy images have also been used to accurately diagnose drug-resistant bacteria, which can definitely reduce the time of diagnosis [23].

3. Raman Spectroscopy for Rapid AST

Recently, Raman spectroscopy, a label-free imaging technique has been employed to quickly predict the antimicrobial susceptibility without the use of standard culturing. In particular, Raman spectroscopy focuses on the biochemical content of the bacterial cells and distinguished between metabolic changes associated with antibiotics. Combined with ML, this method provides high accuracy in the differentiation of susceptible and resistant strains and can be considered a fast substitution for classic AST [24].

4. Optical Imaging Systems

Real-time automated optical imaging systems have been designed to help increase the AST speed by continuously tracking bacterial growth trends. These systems make use of deep learning techniques to scan optical signals and detect the likelihood of bacterial resistance to antibiotics in several hours. Rapid diagnosis of an infection is essential to ensure the proper antibiotic treatment and protect against the development of resistance [24].

5. Challenges and Future Directions

Despite the promising advancements, there are still several challenges concerning the use of imaging techniques in day-to-day clinical practice. There are some concerns that should be met, such as, the implementation of imaging protocols with a goal to standardize them, the reproducibility of obtained data with different bacterial species, and the cost analysis. The further research should be aimed towards increasing the selectivity and sensibility of IK's, design of handheld imaging systems for early diagnostics, and the combination of imaging data with other diagnostic modalities to improve on the understanding of AMR [25].

Conclusion

Antimicrobial resistance (AMR) represents a real and significant threat requiring a complex, trans-disciplinary approach for its containment. The approach of pharmacy, laboratory testing, and medical imaging foreplay in the challenge here and each of them plays a significant role in prevention, diagnosis, and optimizing the treatment.

An example of the involvement is the establishment of ASPs to encourage pharmacists to review and promote the rational use of antimicrobials. Their involvement goes as far as promoting the policies that can help in combating AMR and participating in research that could lead to discovery of new drugs. Culture and susceptibility testing along with rapid diagnostic methods are critical procedural steps to detect resistance and inform relevant treatment. Increased application of molecular techniques and proper utilization of diagnostic stewardship makes the delivery of interventions more accurate and timely, and helps in therapy selection as well as minimization of

misuse of antibiotics. In addition, diagnostic and research laboratories are important for the data to support public health interventions and the mapping of resistance patterns.

Imaging strengthens these efforts by contributing to the diagnosis of infections and investigating disease progression. Novel imaging biomarkers also illuminate the possibility to differentiate bacterial infection from sterile inflammation to minimize added antimicrobial use.

AMR management should be a multidisciplinary topic to harness technological evolution and incorporated expertise. Combined collaborations in pharmacy, laboratory diagnostics, and imaging can improve the health of consumers and check the proliferation of resistance, while ensuring the effectiveness of antimicrobial agents as a resource for generations to come. That requires further investment in education, research to generate evidence, and advocacy for policies to counter this unfolding global problem.

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