Scientific Research Publishing

Pharmacology & Pharmacy, 2025, 16(5), 125-149
https://www.scirp.org/journal/pp
ISSN Online: 2157-9431
ISSN Print: 2157-9423

The Effect of Educational Intervention on Healthcare Workers' Awareness and Knowledge of Antimicrobial Resistance, Stewardship, and Surveillance: Opportunities for Antimicrobial and Diagnostic Stewardship

Steward Mudenda[1,2,3*], Victor Daka[4], Mapeesho Kamayani[5], Shafiq Mohamed[6], Maisa Kasanga[3,7], Webrod Mufwambi[1]

[1]Department of Pharmacy, School of Health Sciences, University of Zambia, Lusaka, Zambia
[2]Education and Continuous Professional Development Committee, Pharmaceutical Society of Zambia, Lusaka, Zambia
[3]Antimicrobial Resistance Coordinating Committee, Zambia National Public Health Institute, Lusaka, Zambia
[4]Public Health Department, School of Medicine, Copperbelt University, Ndola, Zambia
[5]Churches Health Association of Zambia, Lusaka, Zambia
[6]York and Scarborough Teaching Hospitals NHS Foundation Trust, York, UK
[7]Department of Pathology and Microbiology, University Teaching Hospitals, Lusaka, Zambia
Email: *steward.mudenda@unza.zm

How to cite this paper: Mudenda, S., Daka, V., Kamayani, M., Mohamed, S., Kasanga, M. and Mufwambi, W. (2025) The Effect of Educational Intervention on Healthcare Workers' Awareness and Knowledge of Antimicrobial Resistance, Stewardship, and Surveillance: Opportunities for Antimicrobial and Diagnostic Stewardship. *Pharmacology & Pharmacy*, **16**, 125-149.
https://doi.org/10.4236/pp.2025.165009

Received: April 19, 2025
Accepted: May 25, 2025
Published: May 28, 2025

Abstract

Introduction: Laboratories are key in conducting surveillance of antimicrobial resistance (AMR) in healthcare facilities. Therefore, laboratory scientists need to understand the concepts of AMR surveillance and antimicrobial stewardship (AMS) programs. This study evaluated the effect of an educational intervention on the laboratory scientists' knowledge of AMR surveillance, antimicrobial use (AMU), and antimicrobial stewardship (AMS) in Zambia. **Materials and Methods:** A cross-sectional mixed-methods study was conducted in March 2024 among 12 laboratory scientists from five hospitals across Zambia. Data were analyzed using IBM SPSS version 23.0. The Paired t-test was used to determine the significance between the pre-test and post-test results. We grouped qualitative questions into three themes, namely, (i) strengths, (ii) weaknesses and challenges, and (iii) proposed solutions to increase the capacity of laboratories to perform bacteriology, test for AMR, and conduct surveillance. Thematic analysis was utilized to analyze qualitative data. **Results:** This study found a knowledge score of 73% pre-training and 89% post-training, indicating a 16% improvement in their knowledge. The lowest in the pre-training assessment was 60%, while the highest was 80%. Additionally, the lowest

score in the post-training assessment was 75%, while the highest was 100%. Some of the strengths of the laboratories in conducting microbiology included the presence of physical laboratories, the availability of safety cabinets, incubators, autoclave machines, and the availability of beakers, bunsen burners, and centrifuges. However, some challenges faced by the laboratories included a shortage of microbiology staff, a lack of reagents, and inadequate training in bacteriology, AMR testing, and surveillance. **Conclusions:** This study found that educational interventions through AMS training increase awareness and knowledge of AMU, AMR, and surveillance of AMR. Our study found that laboratories had many gaps in conducting AMR surveillance. Therefore, there is a need to provide AMS education and training, mentorship programs, capacity building, and adequate resources to strengthen laboratory capacity to conduct AMR testing and surveillance.

Keywords

Educational Intervention, Surveillance, Antimicrobial Resistance, Antimicrobial Stewardship, Training, Capacity Building, Zambia

1. Introduction

Antimicrobial resistance (AMR) is a global public health problem that has been linked to the inappropriate use of antimicrobials [1]-[5]. The problem of AMR leads to difficulties in treating infections and also contributes to an increase in morbidity and mortality [2] [4] [6] [7]. The wide reach of AMR has also affected global economies [8]-[11]. If this problem is not addressed, it is predicted to cause more than 10 million deaths by the year 2050 [12]-[14]. The human healthcare system consumes a lot of antibiotics that are prescribed empirically due to challenges faced in laboratories, especially in low- and middle-income countries (LMICs) where there are high disease burdens [15]-[17]. Therefore, there is an urgent need to provide interventions that improve awareness of AMR among laboratory staff and strengthen laboratories to conduct AMR testing and surveillance [18]-[22].

Antimicrobial resistance (AMR) occurs as a natural process [23] [24]. However, the AMR process has been worsened by the inappropriate use of antimicrobials in the human, animal, plant, and environmental sectors [1] [4] [12] [25]-[27]. Some drivers of AMR include non-adherence to treatment guidelines, a lack of diagnostic tests to confirm etiology and sensitivity testing, self-medication, poor quality antimicrobials, and low awareness, knowledge, attitudes, and practices concerning antimicrobial use (AMU) [15] [28]-[30].

The laboratory plays a critical role in identifying pathogens and surveillance of AMR [31]-[34]. Laboratory surveillance of AMR guides clinicians to make informed decisions pertaining to patient management [34]-[36]. The World Health Organisation (WHO) has ordered that all member states should develop National Action Plans (NAPs) centered around monitoring antibiotic-resistant bacteria through ro-

bust information on their incidence and prevalence [37]. This has required the setting up of laboratory surveillance systems contextualized to the needs of specific countries as part of antimicrobial stewardship (AMS) programs [38] [39]. Key to the success of the laboratories in mitigating health challenges, such as AMR, is the support of a knowledgeable laboratory workforce [17].

In 2015, the Global Action Plan (GAP) on AMR was established by the WHO, focusing on five objectives, including increasing awareness and knowledge, optimizing antimicrobial use, Infection Prevention and Control (IPC), research, and drug discovery [40]. Countries were guided to develop their NAPs on AMR in line with the GAP to address AMR using a multidisciplinary One Health approach and monitor and review their implementation [41] [42]. Since then, many WHO member states have developed and implemented their NAPs on AMR [43]. The GAP on AMR recommends countries strengthen their surveillance systems to detect AMR across the One Health ecology [40]. Hence, most countries have developed their integrated surveillance systems to monitor AMR using a One Health approach [44]-[48].

Antimicrobial stewardship (AMS) programs have demonstrated that instigating educational interventions improves the awareness of AMR and associated factors [49] [50]. These programs promote the rational use of antibiotics in healthcare facilities and communities [51]. The successful implementation of AMS programs leads to a reduction in the unnecessary use of antibiotics, especially broad-spectrum classes [52], mortality rates, reduction in hospital costs [51] [53], improved cure rates, and surgical antibiotic prophylaxis [54]. The implementation of AMS programs has shown a reduction in the spread of multidrug-resistant organisms in hospitals and communities [55]. Successful implementation of an AMS program necessitates training and interdisciplinary collaboration among various healthcare professionals, including infectious disease physicians, nurses, pharmacists, infection prevention staff microbiologists, administrative staff, and hospital managers [56]. Educational interventions are essential for improving the awareness and knowledge of healthcare workers on AMU, AMR, and AMS [18] [57]-[59]. Significant improvements in healthcare worker's awareness, knowledge, attitudes, and practices regarding AMU and AMR have been noted in previous studies [49] [60]. Hence, educational interventions among laboratory staff can lead to improved diagnostic practices that lead to a reduction in AMR and improved patient outcomes [61].

In Zambia, evidence has shown that some pathogens have developed resistance against common antibiotics used in humans and animals [5] [62]-[72]. The Antimicrobial Resistance Coordinating Committee (AMRCC) of the Zambia National Public Health Institute (ZNPHI) developed and implemented the NAP on AMR with objectives in line with the GAP to combat AMU using a One Health approach [73]. Among the main activities conducted in Zambia included increasing awareness and knowledge of AMR among healthcare workers and the communities, conducting AMR surveillance and establishing and strengthening AMS programs, and research and development [5] [73]-[75]. However, there is a paucity of infor-

mation on the effect of training on AMR and AMS among the targeted audiences, as shown by many studies done among other healthcare workers, excluding laboratory staff [76] [77]. Alongside this, effective surveillance of AMR requires that the laboratory staff are aware of AMR and AMS interventions. Therefore, this study evaluated the effect of educational intervention on laboratory scientists' knowledge of antimicrobial resistance, stewardship, and surveillance in Zambia. The study also evaluated the strengths and weaknesses, and proposed solutions to improve diagnostic stewardship in hospitals in Zambia.

2. Materials and Methods

2.1. Study Design and Sites

This was a cross-sectional mixed-methods study that was conducted among laboratory scientists from March 18, 2024, to March 22, 2024, in the Chongwe district of Zambia. The participants were enrolled in training on bacteriology, AMR, AMS, and laboratory surveillance of AMR. The participants were recruited from five hospitals: Zimba Mission Hospital, St. Dominic's Mission Hospital, Mukinge Mission Hospital, Mwandi Mission Hospital, and Macha Mission Hospital. These facilities were selected because they were enrolled in the national program to establish AMS programs and strengthen laboratory surveillance of AMR. Additionally, the hospitals were selected to undergo mentorship programs in bacteriology and AMR surveillance. This was done in line with the Zambia NAP on AMR to increase awareness and knowledge of AMR among healthcare workers and improve laboratory surveillance of AMR [73]. Therefore, laboratory staff were included in this study as they are the professionals involved in pathogen identification and AMR trends that help clinicians in diagnostic stewardship.

2.2. Sample Size Estimation and Sampling Criteria

A complete enumeration comprising all participants attending a centralized training workshop for medical laboratory personnel was conducted. A total of 12 laboratory scientists from five faith-based hospitals were invited to participate in the training on the basis of having a functional microbiology laboratory. All the invited trainees accepted to participate in the study, giving a 100% response rate

2.3. Data Collection

Data collection involved a self-administered semi-structured questionnaire. The questionnaire was reviewed for content and face validation by public health experts from the University of Zambia and ten laboratory staff from the University Teaching Hospitals, and the feedback given was used to optimize the questionnaire. The questionnaire had two sections: Section A, with 20 multiple-choice questions, and Section B, with three open-ended questions. For the qualitative section, we developed three themes, namely: (i) strengths, (ii) weaknesses and challenges, and (iii) proposed solutions to increase the capacity of laboratories to perform bacteriology, test for AMR, and conduct surveillance. Qualitative data were collected

using a procedure explained by Colaizzi's descriptive phenomenological method [78].

On the first day of the meeting, the participants were given a pre-test to determine their understanding of AMR, AMS, and the role of the laboratory in AMR surveillance. The scores were entered in Microsoft Excel version 2013. After the pre-test, interventional training was conducted for five days by a team of ten experts in AMR and AMS in Zambia, including pharmacists, veterinary practitioners, microbiologists, biomedical scientists, and clinicians.

The training encompassed critical topics, including an Overview of AMR and AMS in Zambia and the role of the AMRCC/ZNPHI in AMR, One Health Situation in Zambia, an overview of microorganisms, Antimicrobial Resistance, Antimicrobial Stewardship and Surveillance, sample processing and testing, Overview of Quality Management Systems (QMS), and biosafety and biosecurity practices in the microbiology laboratory. Further trainings were done on the development and adaptation of Bacteriology SOPs, Antimicrobial Susceptibility Testing, Detecting AMR bacterial types—ESBL, CarbsR, ICR, MRSA, MRS, AmpC, and the roles of laboratory personnel in Antimicrobial Stewardship and Surveillance, and development of Facility Action Plans to combat AMR. At the end of the five-day training, the participants wrote a post-test assessment. The post-test assessment was written, and the scores were compared with the pre-test scores.

2.4. Data Analysis

The collected quantitative data were entered and cleaned in Microsoft Excel version 2013 and analyzed using IBM SPSS version 23.0. The pre- and post-test scores were reported as percentages out of 100%. To determine the normality of the differences in the post and pre-test scores, we performed the Shapiro-Wilks test for normality and found that the difference was normally distributed ($p = 0.407$). The paired t-test was used to determine if there was a significant difference in pre and post-test scores following the intervention. For the qualitative aspect, the responses were grouped into three themes (strengths of laboratories to conduct AMR surveillance, weakness of laboratories to conduct AMR surveillance, proposed solutions to address challenges affecting the surveillance of AMR) and analyzed using thematic analysis. The qualitative data analysis was conducted using Colaizzi's analysis methods [78]. All the responses were grouped into themes and validated by the data collectors. The principal researcher reviewed all interview responses and made necessary corrections within 48 hours of data collection. The responses were also checked for consistency and uniformity in text. Data were analyzed using Colaizzi's seven-step descriptive phenomenological method as follows: 1) Familiarisation and Transcription: Interview recordings were transcribed verbatim. The principal and assistant researchers read and re-read the transcripts to gain an in-depth understanding of the content. 2) Extraction of Significant Statements: Each researcher independently analyzed the transcripts to identify and extract significant statements related to the laboratory staff's awareness and knowledge of

AMU and AMR. 3) Formulation of Meanings: The researchers separately summarised and refined the extracted statements to formulate meanings, focusing on common characteristics. 4) Development of Theme Clusters: The formulated meanings were grouped into clusters of themes through a collaborative process between the principal and assistant researchers. 5) Exhaustive Description: All identified themes were integrated into a comprehensive and detailed description of the laboratory staff's perceptions and experiences regarding AMU and AMR. 6) Identification of Fundamental Structure: The underlying structure of the phenomenon was defined, highlighting the key pathways through which laboratory staff acquire awareness and knowledge about AMU and AMR, as well as the challenges they face in practice. 7) Validation by Participants: The results were returned to a subset of participants for member checking to ensure the accuracy and credibility of the findings.

2.5. Ethical Approval

This study was approved by the Tropical Diseases Research Centre (TDRC) Ethics Committee bearing an approval number TRC/C4/09/2023. All participants were informed about the purpose of the study. All the participants provided informed and written consent for participation in the study.

3. Results

This study enrolled a total of 12 laboratory scientists. The study found that for the majority of the participants, the post-test results were higher than their pre-test results. This study found that the minimum score of participants on AMR, AMS, and surveillance of AMR was 60% in pre-training, while the highest score was 80%. Conversely, the lowest score post-training was 75%, and the highest was 100%. This study found that the overall score pre-training was 73% while that after training was 89%. Therefore, there was a 16% improvement in awareness and knowledge regarding bacteriology, AMR, AMS, and surveillance of AMR. There was a significant difference in pre- and post-test results of participants ($p = 0.002$) (Table 1). These findings indicate that the participants had lower knowledge of bacteriology, AMR, AMS, and surveillance of AMR prior to the training compared to the post-training.

Table 1. Participants' scores regarding bacteriology, AMR, AMS, and laboratory surveillance of AMR and percentage change after the training.

Participant No.	Pre-test score (%)	Post-test score (%)	Percentage rise/drop	P-value
P# 1	60	75	+15	0.002
P# 2	75	80	+5	
P# 3	60	90	+30	
P# 4	70	100	+30	
P# 5	80	95	+15	
P# 6	60	95	+35	

Continued

P# 7	80	95	+15
P# 8	95	95	0
P# 9	80	75	−5
P# 10	80	100	+20
P# 11	80	80	0
P# 12	60	90	+30
Overall	73	89	16

Note: P# = Participant number.

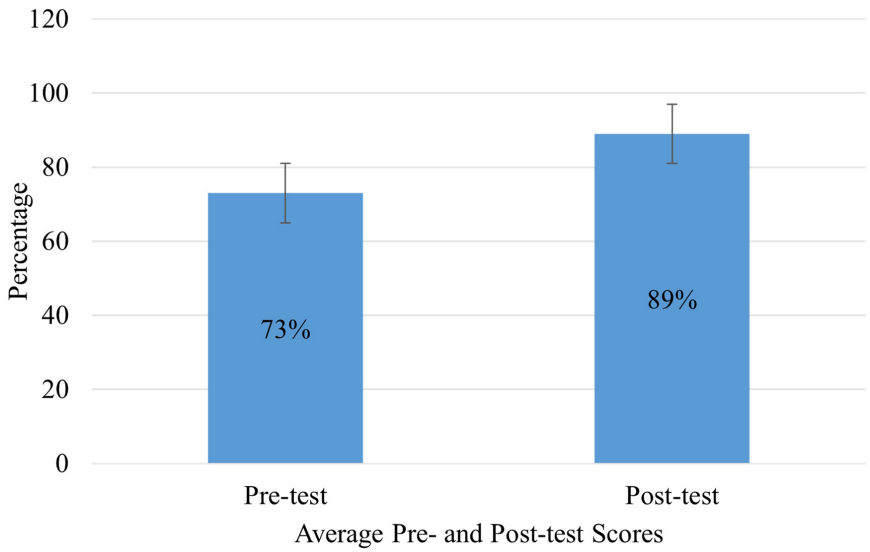

Figure 1. Participants' overall scores regarding awareness of AMR and AMS and the role of the laboratory in conducting AMR surveillance.

This study found that the overall score of knowledge pre-training was 73% while that post-training was 89% (**Figure 1**). This finding indicates an improvement in knowledge after the instigation of education on bacteriology, AMR, and AMS.

Qualitative Interviews Results

Results of the interviews conducted among laboratory scientists indicated that their laboratories had the capacity to conduct bacteriological tests and tests for AMR. Consequently, results demonstrated that the laboratories had weaknesses and faced challenges in conducting AMR testing and surveillance. In this regard, the participants reported some of the proposed remedies to address the challenges and improve the capacity to conduct AMR testing and surveillance.

Strengths of the Laboratory at Your Facility to Conduct Bacteriological Tests, AMR Testing, and Surveillance

Interviewer: What would you say are the strengths of the laboratory at your facility in conducting bacteriological tests, AMR testing, and surveillance?

***Participant No.* 1:** *The strengths of our laboratory to conduct bacteriological tests, AMR testing and surveillance include the presence of a physical laboratory, a safety cabinet, an autoclave machine, running water, and we are committed and willing to implement AMR testing and surveillance.*

Participant No. **2:** *At our facility, the staff are always willing to work in the microbiology department. In addition, the availability of laboratory reagents makes it easy for us to conduct bacteriological and AMR testing. Finally, the staff in the laboratory have the know-how of bacteriology and AMR testing.*

Participant No. **3:** *Our facility has well-trained and qualified staff that can do bacteriology and AMR testing.*

Participant No. **4:** *Some of the strengths of our laboratory to conduct bacteriological and AMR testing include the ability to identify pathogens using gram-staining and the ability to conduct culture and sensitivity of different samples including urine, stool, and pus.*

Participant No. **5:** *Our laboratory has equipment such as a safety cabinet and autoclave machine. This makes it possible for us to conduct some AMR testing in the presence of other laboratory consumables.*

Participant No. **6:** *Some of the strengths of our laboratory to conduct bacteriological and AMR testing include the availability of an incubator. Additionally, we have electricity backup just in case of power loss. Finally, our hospital has been implementing QMS, which is very important.*

Participant No. **7:** *The strength of our facility has most of the equipment needed to conduct bacteriological tests and avenues are available for knowledge sharing within the laboratory personnel. Finally, the stakeholders are easily accessible, and engagement will further strengthen bacteriological activities at our facility.*

Participant No. **8:** *Our hospital administration has been very supportive in terms of making sure our laboratory is provided with some of the reagents needed to strengthen our bacteriology laboratory. We also have the basics needed for smooth running and conducting based on bacteriology.*

Participant No. **9:** *We have an interest in conducting bacteriological tests. We have adequate working space for the bacteriological tests. The capacity building implemented by our partners and the availability of cooperating partners like Churches Health Association of Zambia (CHAZ) to support the laboratory.*

Participant No. **10:** *The facility has the capacity to run a microbiology section as it has most of the required equipment placed in a separate section from other sections. The human resources needed for starters to run the section and capacity building have been done by CHAZ. Furthermore, the laboratory has strong support from hospital management which gives the laboratory an advantage in a lot of areas which includes procurement of consumables.*

Participant No. **11**: *The strengths of the facility laboratory to conduct microbiological tests range from equipment, reagents and competent laboratory personnel. The following equipment is available under our microbiology department, two functional microscopes (light and florescent microscopes), one functional incubator and two biosafety cabinets. Others include readily available culture plates and gram stain reagents. The department has five (5) competent laboratory personnel who are professional and well oriented in laboratory work. One is a scientist and four are biomedical technologists.*

Participant No. **12**: *One of our strengths as a facility is good average staffing who are capable of undertaking bacteriological tests. We have five (5) laboratory scientists and 7 laboratory technologists. We have a variety of equipment, such as distiller, autoclave (being procured now), and a number of glassware such as beakers, Bunsen burners, centrifuges, incubators, biosafety cabinets and refrigerators. The infrastructure is also adequate with dedicated space for bacteriological tests and workflow.*

Weaknesses and Challenges of the Laboratory at Your Facility to Conduct Bacteriological Tests, AMR Testing, and Surveillance

Interviewer: What would you say are the weaknesses and challenges of the laboratory at your facility in conducting bacteriological tests, AMR testing, and surveillance?

Participant No. **1:** *Some of the weaknesses and challenges faced by our laboratory to conduct bacteriological tests, AMR testing and surveillance include unavailability of culture media and antibiotic discs, a lack of space in the microbiology section, shortage of laboratory manpower, unavailability of microbiology fridge for the storage of reagents, and non-servicing of microscopes.*

Participant No. **2:** *Our laboratory faces challenges regarding bacteriology and AMR testing, and these include the unavailability of anaerobic jars, expiry of reagents, and failure to do quality control due to a lack of control organisms as a result of lack of freezers for storage, i.e., 70˚C.*

Participant No. **3:** *Our laboratory does not have equipment like an autoclave machine. In addition, we face challenges with the availability of laboratory consumables like culture media.*

Participant No. **4:** *Some of the challenges experienced by our laboratory to conduct bacteriological and AMR testing include stockout of certain reagents including gram stain, expiring of products such as biochemical powders, expiring of antibiotic discs, a lack of Standard Operating Procedures (SOPs) for performing biochemicals, susceptibility tests, and for identification of ESBL. Moreover, a lack of performing quality controls on the culture media and antibiotic discs. Consequently, we receive very few orders for bacteriological investigations from the clinicians.*

Participant No. **5:** *At our facility, the laboratory has inadequate staff to conduct bacteriology and AMR testing. Another challenge we face as a microbiology laboratory is the unavailability of reagents for bacteriology. On the other hand, the laboratory staff at our facility may have little knowledge of how to perform certain tests like susceptibility testing and results interpretations.*

Participant No. **6:** *One of the weaknesses is that we are understaffed; hence, we get overloaded with a lot of work and we find it difficult to implement active bacteriological testing. Our autoclave machine does not work well, hence, we fail to make media properly. This has also led to the expiry of reagents including media, biochemical powders, and antibiotic discs, thereby causing us to fail to implement bacteriological testing.*

***Participant No.* 7:** *The management at large to have full support in understanding the important program of bacteriological tests. The supply chain of commodities or consumables has not been consistent and makes it a challenge in conducting bacteriological tests. Finally, not all the equipment needed is available.*

***Participant No.* 8:** *the major challenge has been understaffing, as one or two people working on a particular day have to run tests in all the departments, thereby neglecting bacteriological tests. The autoclave malfunctioned, which makes it hard for us to prepare media for culture. The other challenge is that we have expired drugs for susceptibility testing and we do not have the capacity to validate the susceptibility discs, because the facility does not have a −80-degree Celsius fridge for storage of organisms.*

***Participant No.* 9:** *At our facility, we lack equipment, reagents and other laboratory consumables for conducting bacteriological tests. We also have limited human resources in the laboratory to take up additional roles. There are also inadequate supplies for laboratory commodities from the central warehouse at Zambia Medicines and Medical Supplies Agency (ZAMMSA). The staff also have limited capacity on some procedures and interpretation of the results. Finally, management may not fully finance the operations of bacteriological testing.*

***Participant No.* 10:** *There is unavailability of supplies for microbiology, and the standard operating procedures (SOPs). Some laboratory personnel are not interested in microbiology and the facility receives very few requests for microbiology. The clinicians are not patient enough to wait for results for a minimum of 72 hours after a request is made.*

***Participant No.* 11:** *We do not have a functional autoclaving machine. We also have a lack of supply of culture media and other essential bacteriological testing reagents such as sensitivity discs. There is no established Quality Management System (QMS) in microbiology as it is still being developed. Finally, we do not have purpose-built freezers for the storage of reagents.*

***Participant No.* 12:** *We lack enough funds to procure major components of conducting bacteriological tests such as different types of media for culturing, biomedical tests media and bottles and antibiotic discs, beakers, Bunsen burners and Vernier calipers.*

Solutions Would you Propose to Address the Challenges of the Laboratory at Your Facility to Conduct Bacteriological Tests, AMR Testing, and Surveillance

Interviewer: What solutions would you propose to addresses the challenges of the laboratory at your facility to conduct bacteriological tests, AMR testing and surveillance?

***Participant No.* 1:** *I feel that some of the solutions to strengthen our bacteriological tests, AMR testing and surveillance should include procurement of culture media and antibiotics discs, expansion of the microbiology section, deployment of more laboratory staff, procurement of a fridge for storage of reagents, and servicing microscopes.*

***Participant No.* 2:** *To overcome some of the challenges faced in our laboratory,*

there is a need for adequate funding to purchase anaerobic jars and freezers. In addition, there is a need to ensure that laboratory reagents do not expire by sharing the excess with other facilities.

***Participant No.* 3:** *To address the challenges faced in our laboratory, we need a timely and consistent supply of culture media and antibiotic discs. Additionally, we need laboratory materials and equipment like Bunsen burners, autoclaves, cotton swabs, and inoculation loops. On top of that, there is a need for clinicians and laboratory staff to be willing and committed towards ordering and performing culture and sensitivity tests. Finally, retraining laboratory staff regarding bacteriology and AMR testing will be essential in the case of new testing and diagnostic techniques.*

***Participant No.* 4:** *Some of the solutions to strengthen bacteriology and AMR testing in our laboratory include the development of SOPs for the microbiology section and performing quality control on the culture media and antibiotic discs to avoid reporting false results. In addition, educating clinicians on AMR and its effects so that they stop or minimize empirical treatment. By so doing, they will learn to order culture and sensitivity tests for the samples they collect.*

***Participant No.* 5:** *I feel the first solution should be to employ more laboratory staff at our facility so that we can work well since bacteriology requires enough manpower. Alongside this, we need to have a consistent supply of reagents, which could motivate all the microbiology staff. Additionally, conducting capacity building and mentorship training can be of great importance and can boost the morale of laboratory personnel who are performing bacteriological and AMR testing.*

***Participant No.* 6:** *Some of the strategies that can be employed to revamp our microbiology section is to provide capacity building and mentorship programs, especially onsite and through workshops. Additionally, there is a need to fix our autoclave machine and supply us with reagents such as media, biochemical media, sensitivity discs, microbiology SOPs, and guidelines for interpreting susceptibility results. Finally, it will be essential to have a contact person for bacteriology who will be empowered to build capacity at the facility.*

***Participant No.* 7:** *One of the solutions to overcome the challenges through pushing and educating the management on the importance of bacteriological testing. This can also be achieved through continuous impartment of knowledge through staff or laboratory presentations. Finally, lobbying for the equipment needed will facilitate the implementation of bacteriological testing.*

***Participant No.* 8**: *more laboratory personnel should be employed or stationed at the facility. The procurement of an autoclave for the making of media and the constant availability of susceptibility drugs from ZAMMSA can help strengthen the microbiology lab.*

***Participant No.* 9:** *The facility will need to undertake procurement of equipment, reagents, and other consumables need to run the bacteriology laboratory. The improvement of the supply of laboratory consumables. We also need improvement in the staffing levels and a team dedicated to bacteriology on a partic-*

ular shift will be good. Power installation of a reliable power back up system for the laboratory. Provision of onsite mentorship from bacteriology experts. Engagement of management by partners or experts may help them understand the importance of bacteriological testing

Participant No. **10:** *The facility needs to continue sending the laboratory reports on time through the electronic Logistics Management Information System (eLMIS) to Zambia Medicines and Medical Supplies Agency (ZAMMSA) and lobby for some supplies from partners like Churches Health Association of Zambia (CHAZ). As a facility we need to formulate SOPs as soon as possible within three (3) months. The other solution would be through laboratory meetings in order to bring all members of staff to speed and build interest in all laboratory staff with regards to microbiology. The facility will continue having meetings with the hospital management and clinicians on the importance of microbiology which will build confidence and patience among clinicians.*

Participant No. **11**: *Our facility will need a constant supply of reagents for the culturing of organisms for isolation. Constant supply of reagents for susceptibility testing is needed. A well-established QMS for quality and reliable results in microbiology. The other solution is the procurement of storage freezers.*

Participant No. 12: *As mentioned earlier, the autoclave, which we did not have, is underway as it is among the items being provided for our facility. More improvement in the knowledge and skills of laboratory staff is to be realized through weekly meetings on bacteriology. More meetings with the clinicians to update them on the progress in this direction and to talk about the importance of the bacteriological tests based on the one health principle of approach so that they are prepared to request a bacteriology test once we are ready to begin running the tests.*

4. Discussion

This study was conducted to evaluate the effect of training laboratory scientists on knowledge and surveillance of AMR and the implementation of AMS programs. The study also identified some strengths and weaknesses and proposed solutions to improve the surveillance of AMR in Zambia.

The present study found that the knowledge of laboratory scientists of AMU, AMR, AMR surveillance, and AMS was 73% pre-training and 89% post-training, indicating a 16% improvement in their knowledge, which was significant. Therefore, our workshop training found that the laboratory scientists had moderate knowledge of AMR pre-training but good knowledge post-training, thereby translating into the fact that conducting AMS training has the potential to improve awareness and knowledge of AMS. Thus, the training promoted awareness and knowledge of AMU, AMR, surveillance, AMS, and One Health, which is in line with the objectives of the GAP and NAPs of AMR [40]. The effect and impact of AMS programs on improving awareness and knowledge of AMU, AMR, and AMS among healthcare workers have been reported in other studies. Additionally, AMS programs have been reported to improve the rational use of antimicrobials in hospitals [79]. In line with our study,

a survey among healthcare workers from six countries found that AMS interventions lead to improved diagnostic practices and patient outcomes [61]. Hence, there is a need to increase training on AMU, AMR, and diagnostics technology [61].

In this study, the participants reported that strengths existed in their hospitals to conduct AMR surveillance cited some strengths and opportunities, including the presence of a physical laboratory, autoclave machines, safety cabinets, running water, incubator, electricity back-up, hospital leadership support, support from supporting partners like CHAZ, and willingness of the staff to conduct bacteriology and AMR surveillance. The presence of a physical microbiology laboratory infrastructure is key to monitoring the trends and resistance patterns of pathogens isolated from different specimens [34] [80]. The hospital leadership's support of AMR surveillance is essential for the success of efforts to address AMR [81]. Successful implementation of AMS programs and surveillance in hospitals has been reported to be positively influenced by supportive leadership [81].

Operational strengths were evident in this study, particularly in laboratories that have implemented QMS. The standardization and consistency of testing procedures, ensured by QMS, are crucial for maintaining high-quality results. Additionally, strong support from hospital leadership and partnerships with organizations such as the CHAZ provide essential resources and facilitate the procurement of necessary reagents and consumables. These collaborations ensure a steady supply chain, enabling laboratories to function effectively. This indicates the significance of institutional collaborations in addressing AMR and strengthening AMS and surveillance of AMR [82] [83]. Through collaborations, opportunities to address the shortage of laboratory resources can be addressed [84].

This study found that some laboratories faced significant challenges related to infrastructure and equipment, which hinder their ability to conduct bacteriological and AMR testing effectively. Essential equipment, such as fridges or freezers for reagent and organism storage, are either unavailable or malfunctioning. In other instances, the lack of anaerobic jars and a developed Quality Management System further exacerbated the situation. These deficiencies make it difficult to maintain the necessary conditions for accurate testing and storage, directly affecting the reliability and quality of the laboratory's work [61] [85]. This makes the surveillance of AMR in LMICs very complicated [85]. The weaknesses and challenges identified in this study demonstrate opportunities for improving diagnostic stewardship in hospitals [61] [86].

The inconsistencies in the supply chain and availability of consumables were also reported to hamper the efficient operations of the laboratories. As a result, laboratories frequently experience stockouts of essential consumables like culture media, antibiotic discs, and other reagents, with some even expiring due to prolonged storage under suboptimal conditions. This shortage and the expiry of essential materials disrupt routine operations and testing accuracy. Additionally, the inability to perform quality control due to the unavailability of control organisms

and proper storage solutions exacerbates these problems, undermining the laboratory's capacity to deliver reliable results. The challenges identified by this study have been reported before in previous studies conducted in Zambia [87] [88].

Similarly, there is a notable shortage of trained laboratory staff, with existing personnel often overburdened and lacking sufficient knowledge to perform and interpret susceptibility tests accurately. The absence of Standard Operating Procedures (SOPs) for key tests and quality control processes, coupled with limited financial support and low management engagement, hampers operational efficiency and effectiveness. Moreover, the low demand from clinicians for bacteriological investigations and their impatience with the turnaround time for results diminish the perceived value of the laboratory's services, creating a feedback loop that discourages investment and improvement in the microbiology section. The highlighted challenges in this study could be due to a lack of AMS programs in the surveyed hospitals and a lack of laboratory capacity to conduct AMR surveillance, as reported in previous baseline studies [87] [88].

In this study, the participants proposed solutions to the weaknesses faced by their laboratories in conducting AMR surveillance, and these include laboratory staffing, training, mentorship training, implementation of a quality management system, material and laboratory supplies, collaboration and communication with the clinicians and the management is essential AMS surveillance. Some of the solutions proposed by the participants have been reported in other studies and include the need to increase funding, education, and strengthening AMS programs, as well as laboratory resources [61] [86]. Other studies reported on the need for communication between AMS programs, the clinical laboratory, and clinicians to improve AMS surveillance and patient care [32] [89]-[91]. Further, some studies reported that continuous training and staff motivation are all important tools to build this capacity and ensure quality management [37] [87].

We are aware that this study has some limitations. The present study was conducted among laboratory staff from five hospitals. Hence, this affects the generalization of our findings to all hospitals across Zambia. Additionally, our findings may not be generalised to private and public hospitals. However, the qualitative nature of the study provides more details on the strengths and weaknesses of laboratory capacity to conduct AMR surveillance in Zambia and the proposed solutions to improve diagnostic stewardship.

5. Conclusion

This study found that educational interventions through AMS training increase awareness and knowledge of AMU, AMR, and surveillance of AMR. Despite all the hospitals having physical laboratory infrastructure, our study found that the laboratories had many gaps in conducting bacteriology, AMR testing, and surveillance. Therefore, there is a need to provide AMS education and training, mentorship programs, capacity building, and adequate resources to strengthen laboratory capacity to conduct bacteriology, AMR testing, and surveillance.

Acknowledgements

The authors acknowledge the participants who took part in the study.

Funding

This study was internally funded by the authors as part of their routine studies in AMR and AMS.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

[1] Prestinaci, F., Pezzotti, P. and Pantosti, A. (2015) Antimicrobial Resistance: A Global Multifaceted Phenomenon. *Pathogens and Global Health*, **109**, 309-318. https://doi.org/10.1179/2047773215y.0000000030

[2] Murray, C.J., Ikuta, K.S., Sharara, F., Swetschinski, L., Robles Aguilar, G., Gray, A., *et al.* (2022) Global Burden of Bacterial Antimicrobial Resistance in 2019: A Systematic Analysis. *The Lancet*, **399**, 629-655. http://www.thelancet.com/article/S0140673621027240/fulltext

[3] Hutchings, M.I., Truman, A.W. and Wilkinson, B. (2019) Antibiotics: Past, Present and Future. *Current Opinion in Microbiology*, **51**, 72-80. https://doi.org/10.1016/j.mib.2019.10.008

[4] Salam, M.A., Al-Amin, M.Y., Salam, M.T., Pawar, J.S., Akhter, N., Rabaan, A.A., *et al.* (2023) Antimicrobial Resistance: A Growing Serious Threat for Global Public Health. *Healthcare*, **11**, Article 1946. https://doi.org/10.3390/healthcare11131946 https://pubmed.ncbi.nlm.nih.gov/37444780/

[5] Mudenda, S., Mufwambi, W. and Mohamed, S. (2024) The Burden of Antimicrobial Resistance in Zambia, a Sub-Saharan African Country: A One Health Review of the Current Situation, Risk Factors, and Solutions. *Pharmacology & Pharmacy*, **15**, 403-465. https://doi.org/10.4236/pp.2024.1512024 https://www.scirp.org/journal/paperabs?paperid=137998

[6] Sartorius, B., Gray, A.P., Davis Weaver, N., Robles Aguilar, G., Swetschinski, L.R., Ikuta, K.S., *et al.* (2024) The Burden of Bacterial Antimicrobial Resistance in the WHO African Region in 2019: A Cross-Country Systematic Analysis. *The Lancet Global Health*, **12**, e201-e216. http://www.thelancet.com/article/S2214109X23005399/fulltext

[7] Ikuta, K.S., Swetschinski, L.R., Robles Aguilar, G., Sharara, F., Mestrovic, T., Gray, A.P., *et al.* (2022) Global Mortality Associated with 33 Bacterial Pathogens in 2019: A Systematic Analysis for the Global Burden of Disease Study 2019. *The Lancet*, **400**, 2221-2248. http://www.thelancet.com/article/S0140673622021857/fulltext

[8] Dadgostar, P. (2019) Antimicrobial Resistance: Implications and Costs. *Infection and Drug Resistance*, **12**, 3903-3910. https://doi.org/10.2147/idr.s234610

[9] Hillock, N.T., Merlin, T.L., Turnidge, J. and Karnon, J. (2022) Modelling the Future Clinical and Economic Burden of Antimicrobial Resistance: The Feasibility and Value of Models to Inform Policy. *Applied Health Economics and Health Policy*, **20**, 479-486. https://doi.org/10.1007/s40258-022-00728-x

[10] Poudel, A.N., Zhu, S., Cooper, N., Little, P., Tarrant, C., Hickman, M., *et al.* (2023) The Economic Burden of Antibiotic Resistance: A Systematic Review and Meta-Anal-

ysis. *PLOS ONE*, **18**, e0285170. https://doi.org/10.1371/journal.pone.0285170
https://pubmed.ncbi.nlm.nih.gov/35368230/

[11] Shrestha, P., Cooper, B.S., Coast, J., Oppong, R., Do Thi Thuy, N., Phodha, T., *et al.* (2018) Enumerating the Economic Cost of Antimicrobial Resistance per Antibiotic Consumed to Inform the Evaluation of Interventions Affecting Their Use. *Antimicrobial Resistance & Infection Control*, **7**, Article No. 98.
https://doi.org/10.1186/s13756-018-0384-3

[12] Tang, K.W.K., Millar, B.C. and Moore, J.E. (2023) Antimicrobial Resistance (AMR). *British Journal of Biomedical Science*, **80**, Article 11387.
https://doi.org/10.3389/bjbs.2023.11387

[13] de Kraker, M.E.A., Stewardson, A.J. and Harbarth, S. (2016) Will 10 Million People Die a Year Due to Antimicrobial Resistance by 2050? *PLOS Medicine*, **13**, e1002184.
https://doi.org/10.1371/journal.pmed.1002184

[14] O'Neill, J. (2016) Tackling Drug-Resistant Infections Globally: Final Report and Recommendations. The Review on Antimicrobial Resistance.
https://amr-review.org/sites/default/files/160525_Final%20paper_with%20cover.pdf

[15] Otaigbe, I.I. and Elikwu, C.J. (2023) Drivers of Inappropriate Antibiotic Use in Low- and Middle-Income Countries. *JAC-Antimicrobial Resistance*, **5**, dlad062.
https://doi.org/10.1093/jacamr/dlad062

[16] Sartelli, M., Hardcastle, T.C., Catena, F., Chichom-Mefire, A., Coccolini, F., Dhingra, S., *et al.* (2020) Antibiotic Use in Low and Middle-Income Countries and the Challenges of Antimicrobial Resistance in Surgery. *Antibiotics*, **9**, Article 497.
https://doi.org/10.3390/antibiotics9080497
https://www.mdpi.com/2079-6382/9/8/497/htm

[17] Turner, P., Rupali, P., Opintan, J.A., Jaoko, W., Feasey, N.A., Peacock, S.J., *et al.* (2021) Laboratory Informatics Capacity for Effective Antimicrobial Resistance Surveillance in Resource-Limited Settings. *The Lancet Infectious Diseases*, **21**, e170-e174.
https://doi.org/10.1016/s1473-3099(20)30835-5
https://pubmed.ncbi.nlm.nih.gov/33865461/

[18] Mudenda, S., Chabalenge, B., Daka, V., Mfune, R.L., Salachi, K.I., Mohamed, S., *et al.* (2023) Global Strategies to Combat Antimicrobial Resistance: A One Health Perspective. *Pharmacology & Pharmacy*, **14**, 271-328.
https://doi.org/10.4236/pp.2023.148020
http://www.scirp.org/Journal/Paperabs.aspx?paperid=127161

[19] Parveen, S., Garzon-Orjuela, N., Amin, D., McHugh, P. and Vellinga, A. (2022) Public Health Interventions to Improve Antimicrobial Resistance Awareness and Behavioural Change Associated with Antimicrobial Use: A Systematic Review Exploring the Use of Social Media. *Antibiotics*, **11**, Article 669.
https://doi.org/10.3390/antibiotics11050669

[20] Appiah, B., Asamoah-Akuoko, L., Samman, E., Koduah, A., Kretchy, I.A., Ludu, J.Y., *et al.* (2022) The Impact of Antimicrobial Resistance Awareness Interventions Involving Schoolchildren, Development of an Animation and Parents Engagements: A Pilot Study. *Antimicrobial Resistance & Infection Control*, **11**, Article No. 26.
https://doi.org/10.1186/s13756-022-01062-6
https://aricjournal.biomedcentral.com/articles/10.1186/s13756-022-01062-6

[21] Amponsah, O.K.O., Courtenay, A., Ayisi-Boateng, N.K., Abuelhana, A., Opoku, D.A., Blay, L.K., *et al.* (2023) Assessing the Impact of Antimicrobial Stewardship Implementation at a District Hospital in Ghana Using a Health Partnership Model. *JAC-Antimicrobial Resistance*, **5**, dlad084. https://doi.org/10.1093/jacamr/dlad084

[22] Chetty, S., Swe-Han, K.S., Mahabeer, Y., Pillay, A. and Essack, S.Y. (2024) Interprofessional Education in Antimicrobial Stewardship, a Collaborative Effort. *JAC-Antimicrobial Resistance*, **6**, dlae054. https://doi.org/10.1093/jacamr/dlae054

[23] Martínez, J.L. (2012) Natural Antibiotic Resistance and Contamination by Antibiotic Resistance Determinants: The Two Ages in the Evolution of Resistance to Antimicrobials. *Frontiers in Microbiology*, **3**, Article 1. https://doi.org/10.3389/fmicb.2012.00001

[24] Allen, H.K. (2014) Antibiotic Resistance Gene Discovery in Food-Producing Animals. *Current Opinion in Microbiology*, **19**, 25-29. https://doi.org/10.1016/j.mib.2014.06.001

[25] Iossa, G. and White, P.C. (2018) The Natural Environment: A Critical Missing Link in National Action Plans on Antimicrobial Resistance. *Bulletin of the World Health Organization*, **96**, 858-860. https://doi.org/10.2471/blt.18.210898

[26] Ahmed, S.K., Hussein, S., Qurbani, K., Ibrahim, R.H., Fareeq, A., Mahmood, K.A., *et al*. (2024) Antimicrobial Resistance: Impacts, Challenges, and Future Prospects. *Journal of Medicine, Surgery, and Public Health*, **2**, Article 100081. https://doi.org/10.1016/j.glmedi.2024.100081

[27] Booton, R.D., Meeyai, A., Alhusein, N., Buller, H., Feil, E., Lambert, H., *et al*. (2021) One Health Drivers of Antibacterial Resistance: Quantifying the Relative Impacts of Human, Animal and Environmental Use and Transmission. *One Health*, **12**, Article 100220. https://doi.org/10.1016/j.onehlt.2021.100220

[28] Irfan, M., Almotiri, A. and AlZeyadi, Z.A. (2022) Antimicrobial Resistance and Its Drivers—A Review. *Antibiotics*, **11**, Article 1362. https://doi.org/10.3390/antibiotics11101362

[29] Nahar, P., Unicomb, L., Lucas, P.J., Uddin, M.R., Islam, M.A., Nizame, F.A., *et al*. (2020) What Contributes to Inappropriate Antibiotic Dispensing among Qualified and Unqualified Healthcare Providers in Bangladesh? A Qualitative Study. *BMC Health Services Research*, **20**, Article No. 656. https://doi.org/10.1186/s12913-020-05512-y https://bmchealthservres.biomedcentral.com/articles/10.1186/s12913-020-05512-y

[30] Kakooza, S., Tayebwa, D., Njalira, K.R., Kayaga, E., Asiimwe, I., Komugisha, M., *et al*. (2023) Reflections on Drivers for the Emergence and Spread of Antimicrobial Resistant Bacteria Detected from Chickens Reared on Commercial Layer Farms in Mukono District, Uganda. *Veterinary Medicine: Research and Reports*, **14**, 209-219. https://doi.org/10.2147/vmrr.s418624 https://www.dovepress.com/reflections-on-drivers-for-the-emergence-and-spread-of-antimicrobial-r-peer-reviewed-fulltext-article-VMRR

[31] Dakorah, M.P., Agyare, E., Acolatse, J.E.E., Akafity, G., Stelling, J., Chalker, V.J., *et al*. (2022) Utilising Cumulative Antibiogram Data to Enhance Antibiotic Stewardship Capacity in the Cape Coast Teaching Hospital, Ghana. *Antimicrobial Resistance & Infection Control*, **11**, Article No. 122. https://doi.org/10.1186/s13756-022-01160-5 https://pubmed.ncbi.nlm.nih.gov/36192790/

[32] Can, F. and Karatuna, O. (2017) The Role of Microbiology Laboratory in Promoting Antimicrobial Stewardship. In: Pulcini, C., Ergönül, Ö., Eds., *Antimicrobial Stewardship*, Elsevier, 115-128. https://doi.org/10.1016/b978-0-12-810477-4.00009-x

[33] Moirongo, R.M., Aglanu, L.M., Lamshöft, M., Adero, B.O., Yator, S., Anyona, S., *et al*. (2022) Laboratory-Based Surveillance of Antimicrobial Resistance in Regions of Kenya: An Assessment of Capacities, Practices, and Barriers by Means of Multi-Facility Survey. *Frontiers in Public Health*, **10**, Article 1003178.

https://doi.org/10.3389/fpubh.2022.1003178
https://pubmed.ncbi.nlm.nih.gov/36518572/

[34] Musa, K., Okoliegbe, I., Abdalaziz, T., Aboushady, A.T., Stelling, J. and Gould, I.M. (2023) Laboratory Surveillance, Quality Management, and Its Role in Addressing Antimicrobial Resistance in Africa: A Narrative Review. *Antibiotics*, **12**, Article 1313. https://doi.org/10.3390/antibiotics12081313 https://pubmed.ncbi.nlm.nih.gov/37627733/

[35] Yopa, D.S., Anya, P., Mendjime, P., Elouga, T., Nnanga-Nga, E. and Nguefack-Tsague, G. (2023) Evaluation of the Antimicrobial Resistance Surveillance System in Sentinel Sites in Cameroon. *Cureus*, **15**, e40779. https://doi.org/10.7759/cureus.40779 https://www.cureus.com/articles/157468-evaluation-of-the-antimicrobial-resistance-surveillance-system-in-sentinel-sites-in-cameroon

[36] Patel, R. and Fang, F.C. (2018) Diagnostic Stewardship: Opportunity for a Laboratory-Infectious Diseases Partnership. *Clinical Infectious Diseases*, **67**, 799-801. https://doi.org/10.1093/cid/ciy077 https://pubmed.ncbi.nlm.nih.gov/29547995/

[37] Malania, L., Wagenaar, I., Karatuna, O., Tambic Andrasevic, A., Tsereteli, D., Baidauri, M., *et al*. (2021) Setting up Laboratory-Based Antimicrobial Resistance Surveillance in Low- and Middle-Income Countries: Lessons Learned from Georgia. *Clinical Microbiology and Infection*, **27**, 1409-1413. https://doi.org/10.1016/j.cmi.2021.05.027

[38] Morency-Potvin, P., Schwartz, D.N. and Weinstein, R.A. (2017) Antimicrobial Stewardship: How the Microbiology Laboratory Can Right the Ship. *Clinical Microbiology Reviews*, **30**, 381-407. https://doi.org/10.1128/cmr.00066-16

[39] Khadse, S.N., Ugemuge, S. and Singh, C. (2023) Impact of Antimicrobial Stewardship on Reducing Antimicrobial Resistance. *Cureus*, **15**, e49935. https://doi.org/10.7759/cureus.49935

[40] World Health Organization (2015) Global Action Plan on Antimicrobial Resistance. World Health Organization. https://apps.who.int/iris/handle/10665/193736

[41] Avello, P., Collins, L.M., Gómez, S.A., Luna, F., Fernández Miyakawa, M.E., West, H.M., *et al*. (2024) National Action Plans on Antimicrobial Resistance in Latin America: An Analysis via a Governance Framework. *Health Policy and Planning*, **39**, 188-197. https://doi.org/10.1093/heapol/czad118

[42] Willemsen, A., Reid, S. and Assefa, Y. (2022) A Review of National Action Plans on Antimicrobial Resistance: Strengths and Weaknesses. *Antimicrobial Resistance & Infection Control*, **11**, Article No. 90. https://doi.org/10.1186/s13756-022-01130-x https://aricjournal.biomedcentral.com/articles/10.1186/s13756-022-01130-x

[43] World Health Organization (2024) Library of National Action Plans. World Health Organization. https://www.who.int/teams/surveillance-prevention-control-AMR/national-action-plan-monitoring-evaluation/library-of-national-action-plans

[44] Bordier, M., Binot, A., Pauchard, Q., Nguyen, D.T., Trung, T.N., Fortané, N., *et al*. (2018) Antibiotic Resistance in Vietnam: Moving Towards a One Health Surveillance System. *BMC Public Health*, **18**, Article No. 1136. https://doi.org/10.1186/s12889-018-6022-4 http://www.ncbi.nlm.nih.gov/pubmed/30249210

[45] Rüegg, S.R., Antoine-Moussiaux, N., Aenishaenslin, C., Alban, L., Bordier, M., Bennani, H., *et al*. (2022) Guidance for Evaluating Integrated Surveillance of Antimicrobial Use and Resistance. *CABI One Health*, **2022**, 1-13.

https://doi.org/10.1079/cabionehealth.2022.0007

[46] Collineau, L., Bourély, C., Rousset, L., Berger-Carbonne, A., Ploy, M., Pulcini, C., *et al*. (2023) Towards One Health Surveillance of Antibiotic Resistance: Characterisation and Mapping of Existing Programmes in Humans, Animals, Food and the Environment in France, 2021. *Eurosurveillance*, **28**, Article 2200804. https://doi.org/10.2807/1560-7917.es.2023.28.22.2200804

[47] Haworth-Brockman, M., Saxinger, L.M., Miazga-Rodriguez, M., Wierzbowski, A. and Otto, S.J.G. (2021) One Health Evaluation of Antimicrobial Use and Resistance Surveillance: A Novel Tool for Evaluating Integrated, One Health Antimicrobial Resistance and Antimicrobial Use Surveillance Programs. *Frontiers in Public Health*, **9**, Article 693703. https://doi.org/10.3389/fpubh.2021.693703

[48] World Health Organization (2018) Global Antimicrobial Resistance Surveillance System (GLASS) Report: Early Implementation 2017-2018. World Health Organization, 1-260. https://www.who.int/publications/i/item/9789241515061

[49] Tahoon, M.A., Khalil, M.M., Hammad, E., Morad, W.S., awad, S.M. and Ezzat, S. (2020) The Effect of Educational Intervention on Healthcare Providers' Knowledge, Attitude, & Practice Towards Antimicrobial Stewardship Program At, National Liver Institute, Egypt. *Egyptian Liver Journal*, **10**, Article No. 5. https://doi.org/10.1186/s43066-019-0016-5 https://eglj.springeropen.com/articles/10.1186/s43066-019-0016-5

[50] Mudenda, S., Kapolowe, K., Chirwa, U., Chanda, M., Chanda, R., Kalaba, R., *et al*. (2025) Antimicrobial Stewardship Impact on Antibiotic Use in Three Tertiary Hospitals in Zambia: A Comparative Point Prevalence Survey. *Antibiotics*, **14**, Article 284. https://doi.org/10.3390/antibiotics14030284 https://www.mdpi.com/2079-6382/14/3/284/htm

[51] Mahmoudi, L., Sepasian, A., Firouzabadi, D. and Akbari, A. (2020) The Impact of an Antibiotic Stewardship Program on the Consumption of Specific Antimicrobials and Their Cost Burden: A Hospital-Wide Intervention. *Risk Management and Healthcare Policy*, **13**, 1701-1709. https://doi.org/10.2147/rmhp.s265407 https://pubmed.ncbi.nlm.nih.gov/33061704/

[52] Yusef, D., Hayajneh, W.A., Bani Issa, A., Haddad, R., Al-Azzam, S., Lattyak, E.A., *et al*. (2020) Impact of an Antimicrobial Stewardship Programme on Reducing Broad-Spectrum Antibiotic Use and Its Effect on Carbapenem-Resistant *Acinetobacter baumannii* (CRAB) in Hospitals in Jordan. *Journal of Antimicrobial Chemotherapy*, **76**, 516-523. https://doi.org/10.1093/jac/dkaa464

[53] Nathwani, D., Varghese, D., Stephens, J., Ansari, W., Martin, S. and Charbonneau, C. (2019) Value of Hospital Antimicrobial Stewardship Programs [ASPs]: A Systematic Review. *Antimicrobial Resistance & Infection Control*, **8**, Article No. 35. https://doi.org/10.1186/s13756-019-0471-0

[54] Kasanga, M., Chileshe, M., Mudenda, S., Mukosha, R., Kasanga, M., Daka, V., *et al*. (2022) Antibiotic Prescribing Patterns and Prevalence of Surgical Site Infections in Caesarean Section Deliveries at Two Tertiary Hospitals in Lusaka, Zambia. *Pharmacology & Pharmacy*, **13**, 313-330. https://doi.org/10.4236/pp.2022.138024 http://www.scirp.org/journal/PaperInformation.aspx?PaperID=119371

[55] Al-Omari, A., Al Mutair, A., Alhumaid, S., Salih, S., Alanazi, A., Albarsan, H., *et al*. (2020) The Impact of Antimicrobial Stewardship Program Implementation at Four Tertiary Private Hospitals: Results of a Five-Years Pre-Post Analysis. *Antimicrobial Resistance & Infection Control*, **9**, Article No. 95. https://doi.org/10.1186/s13756-020-00751-4 https://aricjournal.biomedcentral.com/articles/10.1186/s13756-020-00751-4

[56] Pallares, C.J., Porras, J., De La Cadena, E., García-Betancur, J.C., Restrepo-Arbeláez, N., Viveros, S.M.C., *et al*. (2023) Antimicrobial Stewardship Programs in Seven Latin American Countries: Facing the Challenges. *BMC Infectious Diseases*, **23**, Article No. 463. https://doi.org/10.1186/s12879-023-08398-3 https://bmcinfectdis.biomedcentral.com/articles/10.1186/s12879-023-08398-3

[57] Kpokiri, E.E., Ladva, M., Dodoo, C.C., Orman, E., Aku, T.A., Mensah, A., *et al*. (2021) Knowledge, Awareness and Practice with Antimicrobial Stewardship Programmes among Healthcare Providers in a Ghanaian Tertiary Hospital. *Antibiotics*, **11**, Article 6. https://doi.org/10.3390/antibiotics11010006

[58] Fuller, W., Kapona, O., Aboderin, A.O., Adeyemo, A.T., Olatunbosun, O.I., Gahimbare, L., *et al*. (2023) Education and Awareness on Antimicrobial Resistance in the WHO African Region: A Systematic Review. *Antibiotics*, **12**, Article 1613. https://doi.org/10.3390/antibiotics12111613 https://www.mdpi.com/2079-6382/12/11/1613/htm

[59] Wesangula, E., Chizimu, J.Y., Mapunjo, S., Mudenda, S., Seni, J., Mitambo, C., *et al*. (2025) A Regional Approach to Strengthening the Implementation of Sustainable Antimicrobial Stewardship Programs in Five Countries in East, Central, and Southern Africa. *Antibiotics*, **14**, Article 266. https://doi.org/10.3390/antibiotics14030266 https://www.mdpi.com/2079-6382/14/3/266/htm

[60] Mudenda, S., Chabalenge, B., Daka, V., Jere, E., Sefah, I.A., Wesangula, E., *et al*. (2024) Knowledge, Awareness and Practices of Healthcare Workers Regarding Antimicrobial Use, Resistance and Stewardship in Zambia: A Multi-Facility Cross-Sectional Study. *JAC-Antimicrobial Resistance*, **6**, dlae076. https://doi.org/10.1093/jacamr/dlae076

[61] Jinks, T., Subramaniam, S., Bassetti, M., Gales, A.C., Kullar, R., Metersky, M.L., *et al*. (2024) Opportunities to Enhance Diagnostic Testing and Antimicrobial Stewardship: A Qualitative Multinational Survey of Healthcare Professionals. *Infectious Diseases and Therapy*, **13**, 1621-1637. https://doi.org/10.1007/s40121-024-00996-1 https://link.springer.com/article/10.1007/s40121-024-00996-1

[62] Shawa, M., Paudel, A., Chambaro, H., Kamboyi, H., Nakazwe, R., Alutuli, L., *et al*. (2024) Trends, Patterns and Relationship of Antimicrobial Use and Resistance in Bacterial Isolates Tested between 2015-2020 in a National Referral Hospital of Zambia. *PLOS ONE*, **19**, e0302053. https://doi.org/10.1371/journal.pone.0302053

[63] Yamba, K., Mudenda, S., Mpabalwani, E., Mainda, G., Mukuma, M., Samutela, M.T., *et al*. (2024) Antibiotic Prescribing Patterns and Carriage of Antibiotic-Resistant *Escherichia coli* and *Enterococcus* Species in Healthy Individuals from Selected Communities in Lusaka and Ndola Districts, Zambia. *JAC-Antimicrobial Resistance*, **6**, dlae027. https://doi.org/10.1093/jacamr/dlae027

[64] ASLM (2022) MAAP Report Zambia 2016-2018. https://aslm.org/flip-books/ZAMBIA/REPORT-ZAMBIA-PRINT.html

[65] Yamba, K., Lukwesa-Musyani, C., Samutela, M.T., Kapesa, C., Hang'ombe, M.B., Mpabalwani, E., *et al*. (2023) Phenotypic and Genotypic Antibiotic Susceptibility Profiles of Gram-Negative Bacteria Isolated from Bloodstream Infections at a Referral Hospital, Lusaka, Zambia. *PLOS Global Public Health*, **3**, e0001414. https://doi.org/10.1371/journal.pgph.0001414 https://journals.plos.org/globalpublichealth/article?id=10.1371/journal.pgph.0001414

[66] Chiyangi, H., Muma, J.B., Malama, S., Manyahi, J., Abade, A., Kwenda, G., *et al*. (2017) Identification and Antimicrobial Resistance Patterns of Bacterial Enteropathogens from Children Aged 0-59 Months at the University Teaching Hospital, Lusaka,

Zambia: A Prospective Cross Sectional Study. *BMC Infectious Diseases*, **17**, Article No. 117. https://doi.org/10.1186/s12879-017-2232-0

[67] Mudenda, S., Malama, S., Munyeme, M., Matafwali, S.K., Kapila, P., Katemangwe, P., *et al.* (2023) Antimicrobial Resistance Profiles of *Escherichia coli* Isolated from Laying Hens in Zambia: Implications and Significance on One Health. *JAC-Antimicrobial Resistance*, **5**, dlad060. https://doi.org/10.1093/jacamr/dlad060 https://academic.oup.com/jacamr/article/5/3/dlad060/7175370

[68] Mudenda, S., Matafwali, S.K., Malama, S., Munyeme, M., Yamba, K., Katemangwe, P., *et al.* (2022) Prevalence and Antimicrobial Resistance Patterns of *Enterococcus* Species Isolated from Laying Hens in Lusaka and Copperbelt Provinces of Zambia: A Call for AMR Surveillance in the Poultry Sector. *JAC-Antimicrobial Resistance*, **4**, dlac126. https://doi.org/10.1093/jacamr/dlac126 https://academic.oup.com/jacamr/article/4/6/dlac126/6955595

[69] Chanda, W., Manyepa, M., Chikwanda, E., Daka, V., Chileshe, J., Tembo, M., *et al.* (2019) Evaluation of Antibiotic Susceptibility Patterns of Pathogens Isolated from Routine Laboratory Specimens at Ndola Teaching Hospital: A Retrospective Study. *PLOS ONE*, **14**, e0226676. https://doi.org/10.1371/journal.pone.0226676 https://pubmed.ncbi.nlm.nih.gov/31869354/

[70] Kasanga, M., Shempela, D.M., Daka, V., Mwikisa, M.J., Sikalima, J., Chanda, D., *et al.* (2024) Antimicrobial Resistance Profiles of *Escherichia coli* Isolated from Clinical and Environmental Samples: Findings and Implications. *JAC-Antimicrobial Resistance*, **6**, dlae061. https://doi.org/10.1093/jacamr/dlae061

[71] Kasanga, M., Kwenda, G., Wu, J., Kasanga, M., Mwikisa, M.J., Chanda, R., *et al.* (2023) Antimicrobial Resistance Patterns and Risk Factors Associated with ESBL-Producing and MDR *Escherichia coli* in Hospital and Environmental Settings in Lusaka, Zambia: Implications for One Health, Antimicrobial Stewardship and Surveillance Systems. *Microorganisms*, **11**, Article 1951. https://doi.org/10.3390/microorganisms11081951 https://www.mdpi.com/2076-2607/11/8/1951/htm

[72] Kasanga, M., Mukosha, R., Kasanga, M., Siyanga, M., Mudenda, S., Solochi, B.B., *et al.* (2021) Antimicrobial Resistance Patterns of Bacterial Pathogens: Their Distribution in University Teaching Hospitals in Zambia. *Future Microbiology*, **16**, 811-824. https://doi.org/10.2217/fmb-2021-0104

[73] Zambia National Public Health Institute (2017) Multi-Sectoral National Action Plan on Antimicrobial Resistance. Zambia National Public Health Institute. https://www.afro.who.int/publications/multi-sectoral-national-action-plan-antimicrobial-resistance-2017-2027

[74] Zambia National Public Health Institute (2019) Prioritised Activities of Zambia's Multisectoral National Action Plan on Antimicrobial Resistance. World Health Organization. https://www.afro.who.int/publications/prioritised-activities-zambias-multi-sectoral-national-action-plan-antimicrobial

[75] Mudenda, S., Lubanga, A., Jamshed, S., Biemba, B., Sakala, R., Chiyabi, M., *et al.* (2025) Point Prevalence Survey of Antibiotic Use in Level 1 Hospitals in Zambia: Future Prospects for Antimicrobial Stewardship Programs. *Infection and Drug Resistance*, **18**, 887-902. https://doi.org/10.2147/idr.s509522 https://www.dovepress.com/point-prevalence-survey-of-antibiotic-use-in-level-1hospitals-in-zambi-peer-reviewed-fulltext-article-IDR

[76] Kalungia, A.C., Mwambula, H., Munkombwe, D., Marshall, S., Schellack, N., May, C., *et al.* (2019) Antimicrobial Stewardship Knowledge and Perception among Physi-

cians and Pharmacists at Leading Tertiary Teaching Hospitals in Zambia: Implications for Future Policy and Practice. *Journal of Chemotherapy*, **31**, 378-387.

[77] Mudenda, S., Hankombo, M., Saleem, Z., Sadiq, M.J., Banda, M., Munkombwe, D., *et al.* (2021) Knowledge, Attitude, and Practices of Community Pharmacists on Antibiotic Resistance and Antimicrobial Stewardship in Lusaka, Zambia. *Journal of Biomedical Research & Environmental Sciences*, **2**, 1005-1014. https://doi.org/10.37871/jbres1343

[78] Morrow, R., Rodriguez, A. and King, N. (2015) Colaizzi's Descriptive Phenomenological Method. *The Psychologist*, **28**, 643-644. http://eprints.hud.ac.uk/id/eprint/26984/

[79] Wang, H., Wang, H., Yu, X., Zhou, H., Li, B., Chen, G., *et al.* (2019) Impact of Antimicrobial Stewardship Managed by Clinical Pharmacists on Antibiotic Use and Drug Resistance in a Chinese Hospital, 2010-2016: A Retrospective Observational Study. *BMJ Open*, **9**, e026072. https://doi.org/10.1136/bmjopen-2018-026072 https://bmjopen.bmj.com/content/9/8/e026072

[80] Okolie, O.J., Igwe, U., Ismail, S.U., Ighodalo, U.L. and Adukwu, E.C. (2022) Systematic Review of Surveillance Systems for AMR in Africa. *Journal of Antimicrobial Chemotherapy*, **78**, 31-51. https://doi.org/10.1093/jac/dkac342

[81] Steinmann, K.E., Lehnick, D., Buettcher, M., Schwendener-Scholl, K., Daetwyler, K., Fontana, M., *et al.* (2018) Impact of Empowering Leadership on Antimicrobial Stewardship: A Single Center Study in a Neonatal and Pediatric Intensive Care Unit and a Literature Review. *Frontiers in Pediatrics*, **6**, Article 294. https://doi.org/10.3389/fped.2018.00294

[82] Ashiru-Oredope, D., Langford, B.J., Bonaconsa, C., Nampoothiri, V., Charani, E. and Goff, D.A. (2023) Global Collaborations in Antimicrobial Stewardship: All Hands on Deck. *Antimicrobial Stewardship & Healthcare Epidemiology*, **3**, e66. https://doi.org/10.1017/ash.2023.122

[83] Veepanattu, P., Singh, S., Mendelson, M., Nampoothiri, V., Edathadatil, F., Surendran, S., *et al.* (2020) Building Resilient and Responsive Research Collaborations to Tackle Antimicrobial Resistance—Lessons Learnt from India, South Africa, and Uk. *International Journal of Infectious Diseases*, **100**, 278-282. https://doi.org/10.1016/j.ijid.2020.08.057

[84] Shrestha, P., He, S. and Legido-Quigley, H. (2022) Antimicrobial Resistance Research Collaborations in Asia: Challenges and Opportunities to Equitable Partnerships. *Antibiotics*, **11**, Article 755. https://doi.org/10.3390/antibiotics11060755

[85] Iskandar, K., Molinier, L., Hallit, S., Sartelli, M., Hardcastle, T.C., Haque, M., *et al.* (2021) Surveillance of Antimicrobial Resistance in Low- and Middle-Income Countries: A Scattered Picture. *Antimicrobial Resistance & Infection Control*, **10**, Article No. 63. https://doi.org/10.1186/s13756-021-00931-w https://aricjournal.biomedcentral.com/articles/10.1186/s13756-021-00931-w

[86] Lapin, J.S., Smith, R.D., Hornback, K.M., Johnson, J.K. and Claeys, K.C. (2023) From Bottle to Bedside: Implementation Considerations and Antimicrobial Stewardship Considerations for Bloodstream Infection Rapid Diagnostic Testing. *Pharmacotherapy*: *The Journal of Human Pharmacology and Drug Therapy*, **43**, 847-863. https://doi.org/10.1002/phar.2813 https://pubmed.ncbi.nlm.nih.gov/37158053/

[87] Yamba, K., Chizimu, J.Y., Mudenda, S., Lukwesa, C., Chanda, R., Nakazwe, R., *et al.* (2024) Assessment of Antimicrobial Resistance Laboratory-Based Surveillance Capacity of Hospitals in Zambia: Findings and Implications for System Strengthening.

Journal of Hospital Infection, **148**, 129-137.
https://doi.org/10.1016/j.jhin.2024.03.014

[88] Shempela, D.M., Mudenda, S., Kasanga, M., Daka, V., Kangongwe, M.H., Kamayani, M., *et al*. (2024) A Situation Analysis of the Capacity of Laboratories in Faith-Based Hospitals in Zambia to Conduct Surveillance of Antimicrobial Resistance: Opportunities to Improve Diagnostic Stewardship. *Microorganisms*, **12**, Article 1697.
https://doi.org/10.3390/microorganisms12081697

[89] Gebretekle, G.B., Haile Mariam, D., Abebe, W., Amogne, W., Tenna, A., Fenta, T.G., *et al*. (2018) Opportunities and Barriers to Implementing Antibiotic Stewardship in Low and Middle-Income Countries: Lessons from a Mixed-Methods Study in a Tertiary Care Hospital in Ethiopia. *PLOS ONE*, **13**, e0208447.
https://doi.org/10.1371/journal.pone.0208447

[90] Chetty, S., Reddy, M., Ramsamy, Y., Dlamini, V.C., Reddy-Naidoo, R. and Essack, S.Y. (2022) Antimicrobial Stewardship in Public-Sector Hospitals in Kwazulu-Natal, South Africa. *Antibiotics*, **11**, Article 881.
https://doi.org/10.3390/antibiotics11070881

[91] Makiko, F., Kalungia, A.C., Kampamba, M., Mudenda, S., Schellack, N., Meyer, J.C., *et al*. (2025) Current Status and Future Direction of Antimicrobial Stewardship Programs and Antibiotic Prescribing in Primary Care Hospitals in Zambia. *JAC-Antimicrobial Resistance*, **7**, dlaf085. https://doi.org/10.1093/jacamr/dlaf085

Appendix

Antimicrobial Resistance and Bacteriology Training Workshop of Laboratory Personnel in Zambia: Strengthening AMR Surveillance

Day	Time	Activity	Facilitator	Chairperson
DAY 1: Monday	08:00 - 08:45	Arrival & Participant Registration		
	08:45 - 09:30	Introductions & Opening Remarks; Training Expectations and Objectives		
	09:30 - 10:30	Pre-test		
	10:30 - 10:45	Health Break		
	10:45 - 13:00	Morning Session: Antimicrobial Resistance		
	10:45 - 11:45	Unit 1: Microorganisms		
	11:45 - 12:30	Unit 2: Antimicrobial Agents		
	12:30 - 13:00	Unit 3: Antimicrobial Resistance (General)		
	13:00 - 14:00	Lunch Break		
	14:00 - 17:00	Afternoon Session: Antimicrobial Resistance, Stewardship, and Surveillance		
	14:00 - 14:35	Unit 4: Antimicrobial Resistance, Stewardship, & Surveillance		W. Mufwambi
	14:35 - 15:15	Unit 5: The Roles of Laboratory Personnel in Antimicrobial Stewardship and Surveillance of AMR		R. Nakazwe
	15:15 - 15:30	Health Break		
	15:30 - 16:00	Unit 6: Sharing of Baseline Findings		
	16:00 - 16:30	Unit 7: Facility Discussions on the Baseline Findings		
	16:30 - 17:00	Unit 8: Participants' Proposed Actions		
	17:00	**End of Day 1**		
DAY 2: Tuesday	08:00 - 08:30	Recap of Day 1		
	08:30 - 09:30	Unit 1: Antimicrobial Resistance in One Health Approach/Discussions		
	09:30 - 10:30	Unit 2: One Health Situation in Zambia		
	10:30 - 10:15	Health Break		
	10:15 - 11:20	Unit 3: Antimicrobial Susceptibility Testing (AST)		
	11:20 - 13:00	Unit 4: Microbial Identification		
	13:00 - 14:00	Lunch Break		
	14:00 - 15:00	Unit 5: Introduction to Quality Management Systems (QMS)		
	15:00 - 15:30	Unit 6: QMS Issues in Facilities: Participants		
	15:30 - 15:45	Health break		
	15:45 - 17:00	Unit 6: QMS Model		
	17:00	**End of Day 2**		
DAY 3: Wednesday	08:00 - 08:30	Recap of Day 2		
	08:30 - 10:00	Unit 1: Overview of AMR and AMS in Zambia and the Role of the AMRCC/ZNPHI in AMR		
	10:00 - 10:30	Unit 2: Group Discussions and the Need for Laboratory Personnel to Be in the AMS Team		
	10:30 - 10:45	Health Break		

Continued

10:45 - 13:00	Unit 3: Document Control, Development of Standard Operating Procedures and Good Documentation Practices
13:00 - 14:00	Lunch Break
14:00 - 15:30	Unit 4: Sample Receipt, Handling, Storage and Inventory
15:30 - 15:45	Health Break
15:45 - 17:00	Unit 5: Laboratory Audit Process, Corrective and Preventive Actions
17:00	**End of Day 3**