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# The role of GLASS (global health through sustainable antimicrobial resistance surveillance) in combatting antimicrobial resistance: challenges and strategies

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**Abstract.** With an estimated 1.27 million fatalities per year and the potential to undermine vital medical treatments, antimicrobial resistance (AMR) is a serious danger to world health. The Global Antimicrobial Resistance and Use Surveillance System (GLASS), which was created by the World Health Organization in 2015 to address this issue, standardized AMR monitoring globally. The application of GLASS throughout Africa, the Americas, and Asia is examined in this review, with a focus on how it has improved clinical treatment, strengthened national monitoring systems, and encouraged antibiotic stewardship. Through a standardized methodology, GLASS has strengthened global AMR responses by supporting robust infection prevention programs, optimizing antibiotic use, and improving laboratory capacities. From 2017 to 2020, GLASS facilitated a 15% increase in countries reporting AMR data, demonstrating its impact on global health management. However, low- and middle-income countries face challenges such as resource limitations and system integration, hindering full implementation.Despite these barriers, GLASS has advanced sustainable AMR surveillance by promoting data consistency and innovative approaches like digital tools and capacity-building programs. Continued efforts are essential to overcome challenges and ensure the long-term success of AMR monitoring systems globally.

## 1 Introduction

### 1.1 Importance of AMR

Antimicrobial resistance (AMR) represents one of the most pressing public health challenges of the 21st century. It leads to an escalating number of deaths and complications due to drug-

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resistant infections, making previously treatable diseases more difficult or even impossible to manage. According to recent estimates, AMR is responsible for 1.27 million deaths annually, and projections indicate that this figure could rise to 10 million deaths per year by 2050 if no significant action is taken [1,2]. The economic toll of AMR is equally alarming, with estimates suggesting a potential global cost of up to $100 trillion by mid-century [3]. The widespread misuse and overuse of antibiotics contribute to the emergence of resistant bacteria, complicating the treatment of infections and threatening the efficacy of essential medical treatments [4,5]. The urgency of addressing AMR has never been greater, as its impact on both human health and the global economy continues to grow.

While there have been various efforts to monitor AMR globally, previous surveillance systems have often been fragmented, inconsistent, and regionally limited. This lack of coordination and standardized methodology has hindered the ability to fully understand the global burden of AMR and to implement effective, coordinated interventions [6,7]. These shortcomings have also prevented the collection of comparable, high-quality data necessary for making evidence-based policy decisions and targeting AMR prevention strategies. Furthermore, the absence of reliable, real-time data on AMR trends has made it difficult to monitor the effectiveness of interventions and to track the spread of resistance patterns on a global scale. Given these challenges, there is an urgent need for a unified system that can provide robust, consistent, and comparable AMR data across countries and regions.

The World Health Organization (WHO) launched the Global Antimicrobial Resistance and Use Surveillance System (GLASS) in 2015. GLASS was designed to standardize AMR and antimicrobial use (AMU) monitoring on a global scale, enabling more effective comparisons of AMR trends between countries and regions. By integrating AMR and AMU data into a single, cohesive framework, GLASS facilitates cross-country analyses and strengthens the global response to AMR. The system also allows for improved tracking of infection prevention and control measures, the effectiveness of antibiotic stewardship programs, and the strengthening of laboratory capacities [6,7]. As GLASS continues to expand globally, it has contributed to a significant increase in the number of countries reporting AMR data. From just 22 countries and 729 monitoring sites in 2018, GLASS now covers 66 countries and more than 64,000 surveillance sites, representing data from over two million patients [8].

This review aims to assess the implementation and impact of GLASS, focusing on how the system has contributed to the standardization of AMR surveillance across different countries and regions. By synthesizing literature on GLASS's achievements and challenges, the review will provide insights into the future of AMR monitoring and offer recommendations for addressing the current gaps in AMR surveillance.

## 2 Method

### 2.1 Search Strategy and Keyword Selection

This review was conducted through a comprehensive search of several key databases, including PubMed, Web of Science, and Google Scholar. The search terms used included "Global Antimicrobial Resistance and Use Surveillance System (GLASS)" combined with keywords such as "GLASS," "AMR," and "Implementation." This combination of terms was selected to capture a broad spectrum of studies on the implementation of GLASS and its role in antimicrobial resistance (AMR) surveillance.

### 2.2 Timeframe and Scope

The inclusion criteria for this review were studies and reports published in English between 2015 and 2022, focusing specifically on the implementation of the Global Antimicrobial Resistance and Use Surveillance System (GLASS). This timeframe was selected because it aligns with the launch of GLASS in 2015, marking the start of its implementation phase. While this period may exclude some early insights into AMR surveillance, it was chosen because it captures the most relevant and recent data regarding the impact of GLASS on antimicrobial resistance (AMR) monitoring and control.

### 2.3 Cross-Verification and Objectivity

The selection process emphasized methodological rigor, relevance to GLASS's objectives, and geographical diversity. Articles were assessed for their quality, and only those that met these criteria were included. To ensure unbiased interpretation of data from various regions, findings were cross-verified using a consistent thematic coding framework. This process allowed for a synthesis of key themes while maintaining objectivity and reducing regional biases. To improve the transparency of the selection process, a flow diagram (Figure 1) has been included to visually represent the steps followed in the article search and selection. This diagram outlines the number of articles identified, screened, and ultimately included in the review.

## 3 Results and Discussion

### 3.1 Country-wide Implementation of GLASS AMR

#### *3.1.1 Morocco*

The implementation of GLASS AMR in Morocco is still in its early stages. Still, the recent inclusion of the country in the system is expected to enhance the accuracy, comparability, and quality of collected data. High rates of resistance were detected for many therapeutically essential antibiotics, including amoxicillin, amoxicillin-clavulanic acid, and co-trimoxazole, in a scoping analysis of epidemiological data on GLASS pathogens in Morocco. There was a generally lower level of resistance to colistin. *Klebsiella pneumonia* and *Acinetobacter baumannii* also exhibited high resistance rates to amoxicillin-clavulanic acid and imipenem, respectively. The median AMR data for *Streptococcus pneumoniae* did not exceed 50.0%. Unstandardized laboratory procedures, clinical settings, and a lack of isolates all contributed to substantial variability in the obtained data, making it difficult to make clear conclusions about AMR in Morocco. It is also important to note that the study's focus on GLASS bacteria may have overlooked other significant pathogens, such as *Helicobacter pylori* and *Pseudomonas aeruginosa*, which are of public health concern in AMR.

Further efforts are needed to establish standardized laboratory methods and enhance surveillance systems to generate more comprehensive data on AMR in Morocco [10]. It is concerning that this review contributed to such a high rate of AMR. Both *E. coli* and *K. pneumoniae* have been studied extensively in relation to urinary tract infections. The latter is responsible for rendering ineffective several of the most regularly used antibiotics, including penicillins and cephalosporins [11]. Although the findings of this study show promise, it is crucial to consider several caveats before reaching definitive conclusions. *Helicobacter pylori* and other crucial pathogens may have been missed because of the intense

concentration of GLASS bacteria [11], and *Pseudomonas aeruginosa* [13,14], which are significant public health concerns in AMR [11].

### *3.1.2 Uganda*

According to Mugerwa et al. [16], how AMR surveillance changed after Uganda adopted the Global Antimicrobial Resistance Surveillance System (GLASS). Uganda has built a laboratory information system for AMR surveillance out of the Ministry of Health laboratory information platforms. The Centers for Disease Control and Prevention and the Global Health Security Agenda have helped the government establish sentinel locations for AMR surveillance research. Twelve hundred and nine samples were taken from four of the country's twelve sentinel locations between 2019 and 2020 in order to cultivate and identify species. The study indicated a normal distribution of cultured samples by age, with most samples coming from individuals between the ages of 15 and 24. The necessity for standardization of laboratory procedures was highlighted by the discovery of discrepancies in the results of culture and sensitivity tests performed on samples from the Kabale area and those from elsewhere. Therefore, raising public awareness, educating the public, and providing training for key stakeholders is perfect for tackling AMR. This may be beneficial to the general public and the community, as well as to politicians and groups representing healthcare workers. The Uganda National Action Plan places a significant emphasis on public antimicrobial resistance (AMR) awareness, education, and training. The plan may be viewed at http://www.cphl.go.ug/policy-documents (accessed on 18 August 2021). Cephalosporins and ciprofloxacin are the most often used antibiotics in Uganda, and preliminary data suggests that these factors, rather than effectiveness or appropriateness, drive antibiotic usage. Despite setbacks, Uganda's use of GLASS for AMR surveillance has shown promising results in improving the country's knowledge of AMR trends and pinpointing problem regions. A comparison of the use and consumption part of AMR monitoring with knowledge of drug-bug resistance trends is highlighted. In order to successfully monitor and regulate AMR, the authors stress the need to address the underlying concerns of health infrastructure, integration, capacity building, and operation. When it comes to creating and executing an effective AMR surveillance plan for human health, Uganda is definitely on the right track and making progress. In the end, changing attitudes and raising awareness among the medical community about all the different aspects and drivers of AMR can best be accomplished by emphasizing and incorporating health practitioners' knowledge, attitudes, and practices (KAP) in the pre-service and post-service curricula. Another research looked into how teaching students to use an AMR dictionary in elementary and secondary schools as a sort of pedagogical training, including policy and civil society professionals, may boost public discourse campaigns [17].

### *3.1.3 Brazil*

The implementation of the Global Antimicrobial Resistance Surveillance System (GLASS) in Brazil has successfully provided valuable insights into the prevalence and susceptibility of antimicrobial-resistant microorganisms in the country. The successful implementation of the BR-GLASS program highlights the importance of a nationwide surveillance system in Brazil to combat the growing threat of antimicrobial resistance. Gram-negative bacteria, especially antibiotic-resistant Acinetobacter baumannii, and Klebsiella pneumoniae, were shown to be prevalent in the data from the pilot experiment. In order to give physicians and epidemiologists a clearer picture of the community and hospital-associated illnesses, the initiative aspires to broaden its reach to include more facilities across different areas in Brazil. The BR-GLASS initiative will serve to enhance empirical prescribing practices and

stewardship programs in the country by addressing trends in antimicrobial resistance and supporting public health policy while also contributing to a growing amount of data for worldwide comparison through the WHO GLASS program [18] This rise could be due to the widespread use of fluoroquinolones as a first-line treatment [19]. Similar results have been seen in other Brazilian investigations. In 2017, 18.6% of all isolates were found to be CoNS, as reported by ANVISA-The Brazilian National Health Regulatory Agency [20].

### *3.1.4 Canada*

The study conducted by Shiona K Glass-Kaastra et al. in 2013 [21] from Canada aimed to describe the antimicrobial use and reported treatment efficacy in Ontario swine using the Ontario swine veterinary-based Surveillance program. The findings from the analysis of 676 records revealed that 80.4% of the records documented the use of antimicrobials, with penicillin, tetracyclines, and ceftiofur being the most often used. Using a model of multi-level logistic regression, an investigation was conducted to determine the relationships that exist between reported treatment failure, antibiotic consumption, diagnosis, and the body system that was affected. GLASS antimicrobial resistance monitoring has the potential to give information on the relationship between reported treatment failure, antimicrobial use, diagnosis, and impacted body systems in swine. This potential was proved by the Ontario Swine Veterinary-based monitoring program. These findings provide light on the selective pressures that contribute to AMR, the need of a preventive approach to herd health, and the need for enhanced immunity methods to limit antibiotic inputs [21]. The presence of secondary bacterial infections or co-infections does not always rule out the benefit of antimicrobial therapy in preventing the worsening of clinical symptoms [22,23]. Guidelines for the appropriate use of antimicrobials in swine emphasize the need to identify the infectious agent while also considering the possibility of secondary bacterial infections [24].

### *3.1.5 Iran*

The study by Safdaris et al. [25] aimed to develop a national antimicrobial resistance surveillance system (AMRSS) for Iran based on the WHO Global Antimicrobial Resistance Surveillance System (WHO GLASS). The researchers examined their structure and operation to understand further what makes different AMRSS tick. This data showed that the study laid the groundwork for a nationwide AMR monitoring program in Iran, complete with processes for collecting data, analyzing samples, reporting findings, and allocating resources. The framework features modules like data mining and dashboards for producing knowledge-based reporting, and it is compatible with SEPAS middleware to provide interoperability and integration. Our AMRSS architecture shares elements with SEPAS, a national system for managing AMR data, including the storage, retrieval, and sharing of standards [26]. Policymakers in Iran will benefit from the deployment of WHO GLASS AMR, and future research can look into further business intelligence capabilities to put into AMRSSs. In conclusion, our research demonstrates the need for a statewide AMR surveillance system in Iran to counteract the danger of AMR and guide public health practices and policies. Indicators were proposed to track and assess how well the national strategy for GLASS was carried out. Several different approaches of AMR surveillance have been discussed in the literature. Active and continuous monitoring, laboratory-based procedures, and routine pathogen-antibiotic combination techniques were shown to be the most frequent AMR surveillance strategies [26].

#### *3.1.6 Japans*

According to Kajihara T. et.al., [29], The WHO Global Antimicrobial Resistance Surveillance System (GLASS) and the Japan Nosocomial Infections Surveillance (JANIS) were compared for their respective de-duplication procedures during 2020 in Japan.. Unlike the JANIS technique, which solely takes into account the initial site of infection, the GLASS method counts people infected at each anatomical location. The study indicated that when comparing blood and urine culture results, the GLASS approach showed between 140,000 and 280,000 more individuals than the JANIS method, with the difference being particularly pronounced for patients aged 65 and over, who were more likely to have several specimen types. Although the JANIS approach for counting isolates produced more accurate results, the resistance levels maintained by counting patients were more consistent with the GLASS findings. Even after splitting the data into three age groups, the maximum difference was 2.8%. In light of these findings, Japan has adopted the specimen-type-stratified GLASS de-duplication approach. The research also contributed to the creation of an Excel application and online resources for generating effective antibiograms for analyzing and countering AMR. In addition, the GLASS technique is more open and transparent, therefore, the software used in it is often free and may be tailored to the user's demands (World Health Organization, 2020). Overall, the study provides valuable information on the implementation of GLASS in Japan and its impact on the surveillance of antimicrobial resistance.

#### *3.1.7 Cambodia*

The study conducted by Reed et al. [31] aimed to investigate the rates of antimicrobial resistance (AMR) in Cambodia and the need for a comprehensive national AMR surveillance program. Escherichia coli was the most often characterized pathogen in the research, which indicated a high prevalence of resistance among human isolates. The frequencies of resistance to ampicillin, third-generation cephalosporins, fluoroquinolones, and gentamicin among human isolates were all above the median. These findings highlight the critical importance of Cambodia's national AMR monitoring program in informing antibiotic prescription and stewardship initiatives. Cambodia has started national AMR surveillance systems for both people and food animals, and it has also joined the Global Antimicrobial Resistance Surveillance System (GLASS) to combat this problem. These initiatives are promising steps toward a more accessible national database on AMR. High rates of resistance were detected among numerous first-line antibiotics, notably among Enterobacteriaceae; while data on AMR in Cambodia is scarce at now, published data shows that AMR rates for GLASS species in Cambodia are equivalent to those in other countries in the area. Cambodia's AMR status can be better understood because to the recently developed national AMR monitoring systems, which should give a more complete and uniform data set. Antibiotic susceptibility testing in Africa and Asia revealed that Asian *E. coli* and *K. pneumoniae* isolates had significant levels of resistance to 3GC*, co-trimoxazole*, and *gentamicin* [32]. Twenty-eight publications documenting Antimicrobial Stewardship in *S. Typhi* reported an average resistance to ciprofloxacin of 0%, according to a recent systematic review of antimicrobial resistance in Africa [33].

#### *3.1.8 Myanmar*

The absence of resources, such as committed and trained employees, computers, and standardized data-gathering formats, has presented substantial obstacles to the implementation of GLASS in Myanmar. Despite these challenges, a study conducted by Sandar et al. [34] reported on the antimicrobial resistance patterns in Myanmar, revealing

that penicillin resistance was found in nearly all *Staphylococcus aureus* isolates, *oxacillin* resistance was found in 70% of isolates, and ampicillin resistance was found in Escherichia coli. In order to overcome these obstacles, the GLASS implementation in Myanmar prioritized training and educating staff members and creating a reliable system for tracking and reporting data. The research did note, however, that it has no way of verifying or correcting WHONET's lack of thorough and consistent data collecting. The study suggests that antibiograms be reviewed and shared on a regular basis so that they can better influence wound care protocols. In addition, better program monitoring and a decrease in the prevalence of multidrug resistance will result from the dissemination of antibiograms [35]. To better inform antimicrobial prescription and stewardship initiatives and increase antimicrobial resistance surveillance, it is essential to overcome the problems experienced in GLASS implementation in Myanmar.

### *3.1.9 Nepal*

The Global Antimicrobial Resistance Surveillance System, often known as GLASS, is an international initiative that aims to enhance the monitoring and reporting of data about antimicrobial resistance (AMR) in Nepal [36], AMR monitoring has been given to the National Public Health Laboratory (NPHL), which has also been given the title of National Reference Laboratory and National Coordinating Centre. Laboratory-based monitoring was first implemented by the NPHL at nine sentinel sites; however, this number has now expanded to 21 locations around the nation. However, there is no standardization between surveillance locations when it comes to the quality, consistency, or frequency of data reporting. Before sending the information to GLASS, it is the responsibility of the NPHL to gather and combine the AMR data from each of these locations. The Nepal Public Health Laboratory (NPHL) first began sending data to GLASS in 2017, and the present research reflects the state of GLASS reporting in 9 out of Nepal's 21 monitoring locations. The purpose of the research was to evaluate the quality of the data used for AMR surveillance with regard to its completeness, consistency, and timeliness, as well as to identify the obstacles faced by non-reporting locations. The researchers carried out a descriptive analysis that was cross-sectional using AMR secondary data from 5 reporting locations. They identified hurdles via the use of a structured questionnaire that was filled out by representatives from 5 reporting sites as well as 4 non-reporting sites. There were 1584 records from reporting sites that were evaluated for consistency and completeness. Depending on the site, 77-92% of those data were consistent, and 88-100% of those records were complete. According to the findings of the research, there is room for advancement in terms of the completeness, consistency, and timeliness of submitting data to GLASS. It was determined that one of the obstacles to exchanging data with the NPHL was the absence of specialist data workers as well as fundamental information technology infrastructure. Researchers may get assistance in reporting data from GLASS if they utilize WHONET, which is software that is used for AMR monitoring. This is helpful for capturing and evaluating data as well as producing statistics in order to enable the development of AMR monitoring reports for hospitals located in LMICs (Low and Middle-Income Countries) [37]. Overall, the NPHL leads Nepal's laboratory-based AMR surveillance with 21 sentinel sites, but improvements are needed in terms of data reporting to GLASS to enhance the country's contribution to global AMR surveillance efforts.

### *3.1.10 Pakistan*

According to a study by Saeed et al. in Pakistan [38], From 2006 to 2018, the country has alarmingly high incidences of antimicrobial resistance (AMR) among GLASS-priority

diseases. Resistance rates were over 50%, with *carbapenem* resistance rates around 30%, according to published data from hospital and community-based research. *Acinetobacter* species have been shown to have high resistance to aminoglycosides and carbapenems among hospitalized patients. *Salmonella Typhi* and *Shigella* species have reportedly developed resistance to ceftriaxone. Methicillin-resistant *Staphylococcus aureus* rose from less than 30% in 2008 to higher than 50% in 2010 in hospitals, and data reveal that the rate of *Neisseria gonorrhoeae* resistance to *fluoroquinolones* was similarly high. There is a lack of knowledge on AMR in pediatric and community-based populations, as well as studies addressing the relationship between patient demographics, underlying co-morbidities, and resistance. In addition, there is a scarcity of research, despite the high rates of AMR documented. The findings of this study support the idea that antibiograms can be used to enhance national AMR monitoring efforts, especially in locations where the scope of national surveillance may be inadequate. Antibiograms are helpful for doctors since they show them the frequencies of resistance in their area. Both published research and antibiograms have provided support for the implementation of GLASS AMR in Pakistan, demonstrating the potential usefulness of both tools in tackling AMR in the country [37]. The evidence supports suggestions that hospitals play a role in the propagation of resistance, and these claims are supported by a number of published research [39–41]. There are growing reports of AMR in the community, including from LMICs [42], and moderate to high rates of AMR among bacterial pathogens associated with bloodstream infections in low and middle-income countries (43–45), according to systematic reviews and meta-analyses [43–45].

### *3.1.11 South Korea*

The implementation of GLASS AMR in South Korea is known as Kor-GLASS. It was established in 2016 and is compatible with the GLASS platform. In order to function, Kor-GLASS adheres to the tenets of localization, harmonization, specialization, and representativeness. Kor-GLASS's successful pilot phase has improved our understanding of the prevalence of various infectious illnesses and the current state of antimicrobial resistance in bacteria across the country. However, concerns about high prices and labor-intensive processes were brought up throughout the pilot, and changes are now being made to address these concerns. In South Korea, AMR is a serious difficulty. Hyukmin Lee et al. (2018) [45] reported that Methicillin-resistant Staphylococcus aureus is widespread, and Acinetobacter baumannii and Pseudomonas aeruginosa isolates collected from hospitals in 2015 showed high rates of imipenem resistance, according to the most recent KARMS report. South Korea's 'one health' strategy for AMR, established in 2017 and set to be further developed by 2019 [46], was inspired by the success of the AMR monitoring system of Kor-GLASS. Comprehensive AMR surveillance data were supplied during the functioning of phase I Kor-GLASS and the described molecular mechanisms of resistance aided our understanding of AMR epidemiology [47]. A more reliable early warning system for developing novel AMR requires molecular characterization. Hence an infrastructure for characterization should be set up. To standardize worldwide AMR monitoring, GLASS has to be updated to include new specimen types, target pathogens, and molecular characterization of AMR determinants.

Changseung Liu et al. (2019) [47] report that Using the baseline year of the first phase of the Kor-GLASS project, we were able to evaluate the true state of AMR in South Korea based on the data. Once the errors were fixed in the original KARMS data, which had overstated AMR due to the repeated isolation of drug-resistant bacteria, the corrected data were compared with data from other countries. Patients in intensive care units had a greater risk of contracting bacteremia from key AMR bacteria, highlighting the necessity of infection control and the need to relieve South Korea's overburdened healthcare system. Kor-GLASS provides reliable, scalable, and effective monitoring of AMR in South Korea, which has been

a significant problem and challenge in the country. The system collects extensive surveillance data, which improves our knowledge of AMR's epidemiology and directs public health officials in their response. The success of Kor-GLASS has prompted the government of South Korea to adopt a "one health" strategy for antimicrobial resistance.

#### *3.1.12 Laos*

To track the rise and spread of AMR in humans and animals, Laos has adopted the Global Antimicrobial Resistance Surveillance System (GLASS). Luckily, the severity of the AMR crisis in Laos is now lower than in other nations, offering a chance to intervene before it worsens. Nonetheless, Laos must take measures to safeguard its people from AMR's possible risks. New antibiotic stewardship recommendations decreased antibiotic overuse, increased surveillance, and more knowledge of AMU and AMR are all examples of these tactics. The availability of viable medicines for the treatment of bacterial illnesses depends on these treatments stopping the spread of antimicrobial resistance [48]. In 2017, as part of an initiative to monitor antimicrobial usage and resistance in Laos, the government began contributing data on hospital antimicrobial prescription to the Global-PPS of antimicrobial consumption and resistance [49].

#### *3.1.13 Thailand*

According to the findings of two studies that were carried out in Thailand, Limited finances, a lack of people training, and insufficient laboratory facilities have been some of the biggest roadblocks to implementing the Global Antimicrobial Resistance Surveillance System (GLASS). However, sustained funding and investment in human resources, infrastructure, and technology have been identified as success factors for GLASS implementation in Thailand. Despite the challenges, GLASS has the potential to improve the understanding and management of antimicrobial resistance in Thailand [50]. In research that was carried out at Siriraj Hospital, it was discovered that the GLASS AMR system was more effective than the laboratory-based monitoring system for blood culture specimens in patients who had bacteremia. It was shown to be advantageous for antimicrobial resistance surveillance as well as the process of generating local antibiotic treatment guidelines to use blood culture findings in conjunction with patient clinical data. GLASS was able to give useful data for calculating and tracking AMR consumption and usage, as well as its impact on health and the economy. However, the GLASS method required far more time and capital than the laboratory-based strategy. Along with the request for clinical specimen culture, the appropriate employees in Thailand are required to supply all pertinent patient clinical data. Only then can GLASS be completely implemented there. One approach that might be considered is to just activate GLASS for a short time period every other year [51]. With continued efforts to address the identified challenges and leverage the success factors, GLASS implementation can contribute to more effective monitoring and management of antimicrobial resistance in Thailand.

### 3.2 Regional Implementation of GLASS AMR

Our findings cover different aspects of global antimicrobial resistance (AMR) surveillance and its impact on different countries and regions, including low and middle-income countries, the Middle East, and Sub-Saharan Africa.

### *3.2.1 Low and Middle-Income Countries*

The implementation of GLASS AMR proved difficult in low- and middle-income nations because of the inadequate resources and capacity in those countries [52]. In order to find a solution to this problem, a set of guidelines that are consistent with the GLASS protocols but are expressly intended for low-income nations was produced. While at the same time defining essential procedures, this guideline allows for flexibility across a variety of different systems, which helps to guarantee that the data obtained is legitimate and comparable. The GLASS initiative gathers health intelligence data and makes it available to support the development of evidence-based interventions locally, nationally, and worldwide. The development of AMR monitoring is necessary to address the worldwide problem of drug-resistant illnesses caused by bacteria that have a growing resistance to antimicrobials. In low-income countries, AMR monitoring systems will evolve gradually beyond what is now specified in accordance with GLASS, incorporating agriculture (including animal health) and the environment in the context of a One Health strategy.

National Coordinating Centres (NCCs) should think about these tasks as the capability for AMR monitoring in clinical settings improves; they were not included in the first recommendation since parallel laboratory systems normally perform them. The aggregate national wholesale data or point prevalence surveys of antimicrobial prescriptions by indication at regular intervals might provide useful context for interpreting microbiological results. The findings of AMR monitoring should be used to shape public health policy at the local, national, and international levels. The genesis and development of AMR can be better comprehended if monitoring systems serve as a hub for regional, national, and worldwide partnerships to address research issues. This will help in the creation of much-required intervention methods down the road.

In addition, the registration of several lower-middle-income countries in GLASS will enable them to strengthen and receive technical support from registered members in AMR surveillance and establish an informal regional expert consultation group on AMR surveillance [53]. Implementing GLASS AMR in low-middle-income countries will enable them to collect data on antimicrobial resistance in a standardized way comparable to global data. This will help monitor AMR development, identify hotspots, and inform interventions. It is important to conduct AMR monitoring in low-income countries since these nations bear the worst burden of infectious illnesses and have the least amount of data available. GLASS AMR will also contribute to the global response to AMR by improving the availability and quality of data on antimicrobial resistance and supporting evidence-based interventions to reduce the spread and impact of drug-resistant infections. This is particularly important in low-income countries where access to effective antibiotics is limited, and the consequences of drug-resistant infections are more severe [52].

### *3.2.2 Middle East*

The GLASS was developed to combat the AMR epidemic, which affects people all around the globe. However, there is a lack of uniformity in the way that different regions take to AMR research, which provides barriers to the implementation of GLASS. This makes it tough to generalize about the frequency with which particular forms of resistance occur within a given population. Recent research into antimicrobial resistance in the Middle East is mostly hospital-based and cross-sectional in design, with a focus on convenience sampling. There is also a deficiency in statistical methods that account for the wide variety of confounding factors that can contribute to AMR's genesis and dissemination. In spite of these challenges, recent research found that methicillin-resistant S. aureus isolates, Acinetobacter spp., Enterobacteriaceae, and carbapenem-resistant and extended-spectrum beta-lactamase

(ESBL) generating bacteria were all abundant in the Middle East. Multiple analyses have shown that the Syrian conflict has raised the likelihood of antimicrobial resistance (AMR) development and transmission among populations who have been affected, both locally and internationally, due to the large number of countries where refugees have fled [54]. The research proposes that countries in the Middle East should embrace the recommended standardized techniques endorsed and supported by GLASS for AMR research and reporting in order to enhance the accuracy, quality, and comparability of the data collected on AMR in the region. In addition to this, it suggests putting a greater focus on research that is population-based as well as research that is based on primary care, as well as the deployment of adequate AMR surveillance systems and antibiotic stewardship programs, particularly in countries that are currently experiencing conflict. Given the prevalence of *Acinetobacter spp.* in wounds resulting from conflict, the high antibiotic resistance rates seen in some GLASS pathogens, in particular, need further research [55].

### *3.2.3 Africa*

Egypt, Ethiopia, Madagascar, Malawi, Mali, Mozambique, Nigeria, South Africa, Sudan, Tunisia, Uganda, and Zambia are some of the African nations that contributed data to the Global Antimicrobial Resistance and Use Surveillance System (GLASS) between 2017 and 2019. This article focuses on the system's deployment and the effect it has had on the continent. It was first proposed by the World Health Organization (WHO) to help the improvement of the AMR evidence base. Even though some African countries are still struggling to construct their national AMR surveillance systems and have not provided data, the data submitted to GLASS and the information collected through questionnaires on the constraints, perceived impact, and value in GLASS participation show that more and more countries are working toward reporting data in a comprehensive and systematic manner. Better clinical treatment and antibiotic dosage are the end results of GLASS participation since it is linked to improved national monitoring systems. The expansion of regular monitoring capability for several nations as well as the conduct of surveys that adequately characterize the extent of antimicrobial resistance throughout the continent, are both upcoming developments. The author concludes that participation in GLASS is facilitating the creation of a reliable and efficient global monitoring system in the future. This approach is flexible enough to be used in a wide range of political and economic settings while still providing relevant and useful information. The GLASS program's focus on antimicrobial resistance is only one part of the Member States' efforts to improve health security, strengthen health systems, and ensure universal health care throughout Africa [56].

Another research conducted in Africa by Kariuski investigates the execution of national action plans (NAPs) to prevent antimicrobial resistance in countries located in Sub-Saharan Africa (SSA). The disproportionate impact of antimicrobial resistance (AMR) in SSA is caused in part by poverty, inadequate regulation of antimicrobial usage, and a lack of alternatives to ineffective antimicrobials. The majority of nations have already embraced the global action plan, but there is still more work to be done to execute country-specific NAPs. The conclusion of the article is that in order to successfully combat AMR in SSA, a concentrated "One Health" strategy will be required. This approach will need to include infection prevention and control programs, as well as water, sanitation, hygiene, and antimicrobial stewardship initiatives. At the national level, initiatives to address antimicrobial resistance (AMR) will be informed by continuously generating data and implementing the One Health concept. The efficient and successful implementation of infection prevention and control, hand hygiene, and antimicrobial stewardship programs will also be crucial in the fight against antimicrobial resistance in a cost-effective manner [57].

In addition to being on the WHO Model List of Essential Medicines as a first- or second-choice empirical treatment option for definite infectious syndromes, ciprofloxacin is on the 'watch' list of the WHO 2021 AWaRe Classification, which consists of antibiotics with a higher potential to induce resistance. Every country must implement systems for continuous data collection to ensure that the reported AMR data from the spread of all indicated resistance patterns are accurately reflected. Some examples of such actions include conducting prevalence surveys or enhancing surveillance activities [57].

The majority of nations did not yet have comprehensive data available since it was still early in the course of the pandemic, and it was difficult to accurately examine changes in AMR rate. Nevertheless, there have been reports of reductions in monitoring capacity, which would restrict the ability to give statistics on actual changes in AMR. In the context of the COVID-19 pandemic, several hospital studies have indicated an increase in the identification of diseases and outbreaks caused by AMR threats, such as *carbapenemase*-producing *Enterobacterales* [58–61]. Surveillance systems need to be able to perform regular monitoring of AMR (for example, according to GLASS requirements) and be able to be maintained even during widespread disasters [9].

## 4 Conclusion

This review assessed the implementation and impact of the Global Antimicrobial Resistance and Use Surveillance System (GLASS) and highlighted its critical role in monitoring and controlling the spread of antimicrobial-resistant bacteria. The analysis emphasized the importance of accurate, timely data collection, efficient data sharing, and standardized methodologies to improve AMR surveillance outcomes. Continued investment in the development and enhancement of GLASS and broader AMR surveillance systems is necessary. Strengthening international collaboration and fostering public-private partnerships will be instrumental in tackling the growing threat of antimicrobial resistance. To further strengthen global AMR control, future research should prioritize improving data quality and accessibility, utilizing innovative technologies such as artificial intelligence and predictive modeling to enhance data interpretation and forecasting. Addressing challenges faced by low- and middle-income countries in adopting effective surveillance systems remains a priority to ensure equitable global progress. Although significant strides have been made, sustained and coordinated global action is essential to combat AMR and preserve antibiotic efficacy for generations to come. With continued commitment and innovative collaboration, there is a strong potential to control and reduce the impact of AMR through collective efforts.

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