National antimicrobial resistance surveillance systems and participation in the Global Antimicrobial Resistance Surveillance System (GLASS)

A guide to planning, implementation, and monitoring and evaluation

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Acronyms

AMR	antimicrobial resistance
AST	antimicrobial susceptibility testing
CLSI	Clinical and Laboratory Standards Institute
EQA	external quality assurance
EUCAST	European Committee on Antimicrobial Susceptibility Testing
GLASS	Global Antimicrobial Resistance Surveillance System
IQC	internal quality control
M&E	monitoring and evaluation
NCC	national coordinating centre
NFP	national focal point
NRL	national reference laboratory
MIC	minimum inhibitory concentration
SOPs	standard operating procedures
WHO	World Health Organization

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1. Setting up a national AMR surveillance system

1.1 Introduction

The World Health Organization (WHO) has developed the Global Antimicrobial Resistance Surveillance System (GLASS) to support the implementation of the Global Action Plan on antimicrobial resistance[1] (AMR). GLASS promotes and supports standardized antimicrobial resistance (AMR) surveillance worldwide. The ***GLASS Manual for Early Implementation***[2] (hereinafter called the *GLASS Manual*) provides details of the proposed approach and defines targets for the surveillance of resistance in common bacterial pathogens.

The overall goal of GLASS is to enable standardized, comparable and validated data on AMR to be collected, analysed and shared with all countries and partners. Data collected will inform decision making and provide the evidence base for action and advocacy.

In order to gather and analyse data from countries, GLASS is reliant upon countries to conduct their own national surveillance. As such, one of the main objectives of GLASS is to encourage and facilitate the establishment of national AMR surveillance systems that are capable of monitoring AMR trends and producing reliable and comparable data on a regular basis.

A well-functioning national AMR surveillance system is also vital in planning and implementing the national AMR strategy. The objectives and targets that are defined in the national strategy inform the definition of variables to be monitored and implementation steps of the AMR surveillance programme, enabling countries to generate relevant, usable information in a timely manner. This information will also inform and assist in monitoring the impact of efforts and interventions, be they at the local, national or global level, to contain AMR.

Data on AMR of different types and from a variety of different sources are required to inform control strategies. These include data on AMR trends in humans, animals, food, plants, and the environment; antimicrobial medicine use/consumption in humans, animals and plants; and environmental usage. **In the early implementation phase, however, GLASS will focus on surveillance of priority bacterial pathogens that are relevant to human health**. This document provides specific guidance for AMR surveillance in the human health sector.

GLASS promotes links between AMR data from the human sector and surveillance data from other sectors. National authorities should keep in mind the importance of conducting AMR surveillance in other sectors, and as such should promote an integrated surveillance approach, making links across multiple sectors wherever appropriate.

1 Global Action Plan on antimicrobial resistance. World Health Organization (2015) available at http://apps.who.int/iris/bitstream/10665/193736/1/9789241509763_eng.pdf

2 Global Antimicrobial Resistance Surveillance System: Manual for Early Implementation. World Health Organization (2015) available at http://www.who.int/antimicrobial-resistance/publications/surveillance-system-manual/en/

Flexibility has been built into the global system to enable each country to participate in GLASS from the outset, while gradually establishing and strengthening the core components of the national AMR surveillance system to progressively build capacity to share data.

This document complements the *GLASS Manual*. It is primarily intended to benefit capacity building in countries with limited resources, particularly in the planning phase of setting up a national AMR surveillance in the human sector. It is one of several documents and tools that are available to support the implementation of national AMR surveillance systems and participation in GLASS.

This guide outlines the key steps in planning and establishing a national AMR surveillance system. It describes the three core components of the system and how each should function and work together. It will also assist countries in formulating and implementing a monitoring and evaluation (M&E) strategy for the system. M&E is key in ensuring sustainability and development of the system to maintain national surveillance over the long term.

The primary target audience for this guide is the national coordinating centre, the institution that will have been mandated to set up the national AMR surveillance system. However, this document may also be useful to other stakeholders such as:

- staff of the surveillance and epidemiology units in ministries of health;
- programme managers at national level;
- regional and district level surveillance officers;
- public health laboratory personnel at all levels; and
- other professionals with a role or interest in AMR surveillance systems.

1.2 Conducting a situation analysis

Prior to initiating the process of establishing a national surveillance system, it is advisable to conduct a situation analysis. This will help to:

- identify available resources and capacities;
- assess the current national AMR situation;
- assist in defining priorities and needs; and
- inform the overall national strategy for AMR surveillance.

Important questions to consider when conducting a situation analysis of the current AMR situation include:

- what data are available on the magnitude and impact of AMR in the country?
- what surveillance policies and regulations are in place?
- what capacities and structures exist to conduct surveillance, including laboratory capacity?
- who are the relevant stakeholders and where are available resources?

Some countries may already have comprehensive national AMR surveillance systems in place, some may be collecting national AMR data only for selected pathogens, while others may have just begun

the process of planning a national AMR surveillance system. The AMR situation and existing capacities will influence strategic planning and prioritization, which should aim wherever possible to build on existing systems and programmes. Tools to assess the national AMR surveillance situation and capacities have been developed and are available from the WHO website or through the GLASS secretariat.[3]

1.3 The core components of a national AMR surveillance system

A well-functioning national AMR surveillance system typically comprises three core components:

- a national coordinating centre (NCC);
- a national reference laboratory (NRL); and
- AMR surveillance sites.

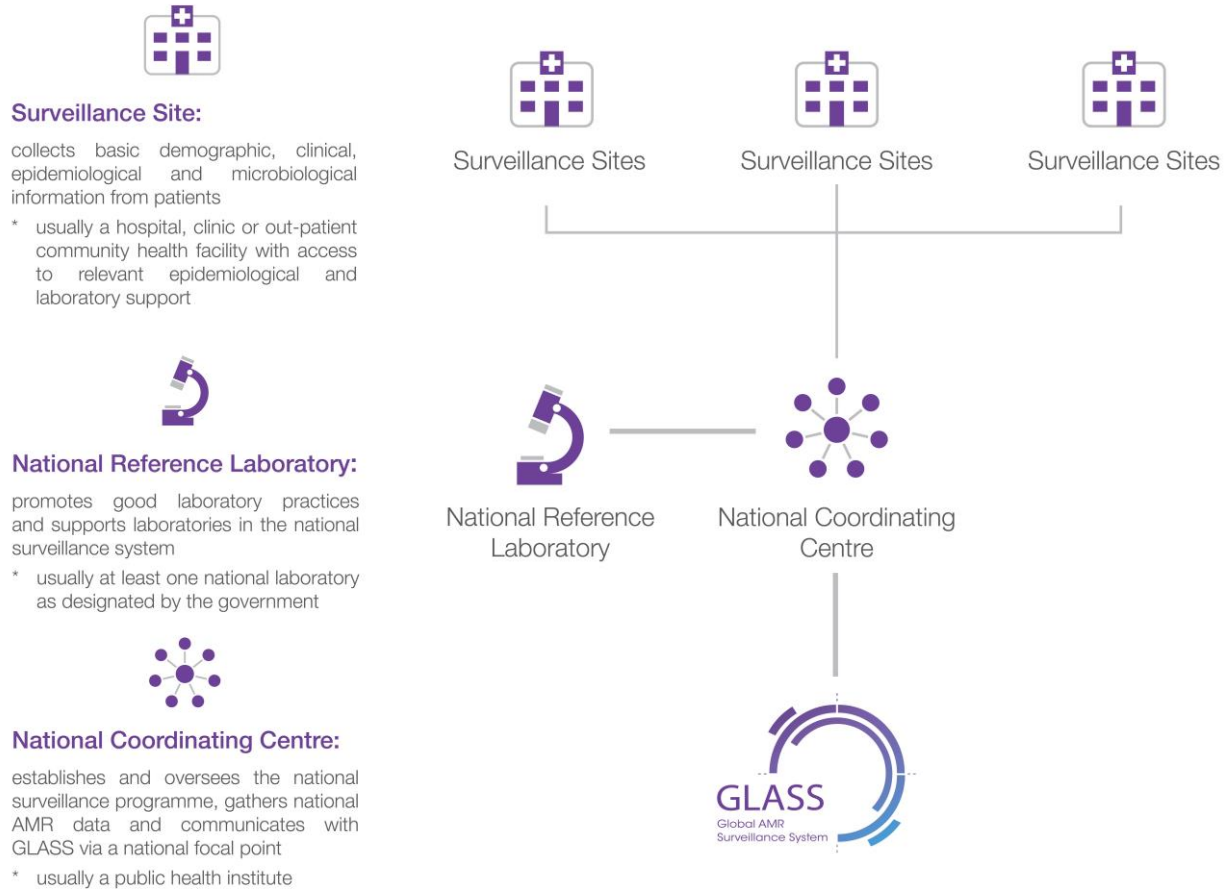

Figure 1: The three proposed core components of a national AMR surveillance system participating in GLASS

[3] National AMR surveillance and GLASS: core components checklist and questionnaire available at http://www.who.int/antimicrobial-resistance/global-action-plan/surveillance/supporting-documents-tools/en/ or from the GLASS Secretariat glass@who.int

Each of these components will need to have clearly defined roles and responsibilities, as well as mechanisms that will ensure good collaboration between them on a daily basis. This is essential in establishing and maintaining continuous AMR surveillance.

Core component 1: the National Coordinating Centre (NCC)

The National Coordinating Centre (NCC) is an institution that has been designated by the national authorities to oversee the development and functioning of the national AMR surveillance system. It is usually, but not always, a public health institution.

NCCs are usually experienced in conducting and managing national surveillance and have epidemiological expertise as well as access to clinical and microbiological expertise whenever needed. The NCC will need a defined structure for surveillance coordination and data management, and will need to collaborate closely with both the national reference laboratory (NRL) and the surveillance sites that have been identified to participate in the system. It is recommended that a multidisciplinary team be established comprising a range of disciplines e.g. epidemiologists, microbiologists, clinicians, infectious disease experts and data managers, with one designated focal point for AMR surveillance and GLASS.

Box 1: Sample terms of reference for the National Coordinating Centre (NCC)

1. Define AMR surveillance objectives within the national AMR strategy
2. Facilitate linkages with AMR surveillance across human health, animal health and environmental sectors
3. Develop or adapt national AMR surveillance standards, protocols and tools and coordinate their dissemination
4. Provide guidance and information on data collection and reporting to the national reference laboratory and AMR surveillance sites
5. Monitor and evaluate the AMR surveillance system on an ongoing basis
6. Define strategy for participation in GLASS
7. Assure data management structure and format and IT solutions
8. Select and facilitate enrolment of surveillance sites
9. Coordinate collection and compilation of national AMR data
10. Conduct data analysis and quality assurance
11. Analyse and feedback AMR surveillance results to AMR surveillance sites in collaboration with the national reference laboratory
12. Aggregate and report national AMR data and data on implementation status of national AMR surveillance system to GLASS

Core component 2: the National Reference Laboratory (NRL)

The second core component of the national AMR surveillance system is the national reference laboratory. Laboratory capacity and capability are essential in order to conduct microbiological diagnostics following quality-assured procedures.

The primary function of the NRL within the AMR surveillance system is to promote good microbiological laboratory practices, including adapting and disseminating microbiological methods, standards and protocols, to serve as a resource and coordination point for quality assessment in laboratories, and to facilitate collaboration with AMR surveillance sites on all laboratory matters relating to AMR.

Box 2: Sample terms of reference for the National Reference Laboratory (NRL)

1. Serve as a resource and coordination point for laboratory expertise and share information and advice with relevant stakeholders
2. Liaise with the national coordinating centre
3. Develop, maintain, and share relevant reference material
4. Promote good laboratory practice and provide guidance and technical support for quality management, pathogen isolation and identification and antimicrobial susceptibility testing (AST) methodology
5. Support capacity building of laboratories serving AMR surveillance sites through oversight and training
6. Organize or facilitate participation in external quality assurance (EQA) schemes for laboratories serving AMR surveillance sites, review EQA performance of participating laboratories and provide feedback on EQA results to laboratories
7. Provide guidance on isolates that should be sent for confirmatory testing to the NRL
8. Perform confirmatory testing, e.g. isolates with rare and unusual resistance patterns and resistance mechanisms
9. Collaborate and conduct research in the field of microbiology

The national surveillance strategy may indicate the need to have several reference laboratories to support laboratories in different regions, particular in large countries. Overall coordination by a single national laboratory to oversee and support regional reference laboratories is however desirable.

Core component 3: the AMR surveillance sites

The backbone of the national AMR surveillance system is the network of AMR surveillance sites that are dotted around the country. These sites are usually health-care centres and hospitals staffed with health-care workers at the front line of clinical work.

Sites that are deemed suitable for AMR surveillance (in- and outpatient health-care facilities from the public and, if applicable, the private sector) are selected by the NCC. These sites should have access to epidemiological support and a microbiology laboratory, and should be actively promoting diagnostic stewardship.[4] The commitment and active support of clinical staff, administration and management at the AMR surveillance site is essential in order to conduct AMR surveillance according to the requirements and standards of the national system and GLASS, and to maintain long-term sustainability.

The sites will be actively collecting samples taken from patients and forwarding these together with all the necessary patient and demographic information to the relevant laboratories. As health-care centres, their priorities will be the treatment and recovery of their patients and a key function of these sites will be to apply their clinical expertise that is informed by quality-assured microbiological findings and surveillance data to select and prescribe the most appropriate treatment.

Box 3: Sample terms of reference for the AMR surveillance sites

1. Promote diagnostic stewardship activities on site
2. Collect clinical specimens and clinical, demographic and epidemiological data following standard protocols
3. The microbiology laboratory providing support to the surveillance site should:
   a. isolate and identify pathogens, perform AST according to standards and report microbiological information derived from the tested clinical specimen
   b. participate in a proficiency testing scheme
4. Compile and manage basic clinical, demographic and epidemiological information derived from tested clinical specimens
5. Feedback/discuss locally-generated surveillance data to inform local treatment guidelines and AMR control strategies
6. Report quality-assured AST results and relevant core patient data to NCC

[4] Diagnostic stewardship: A guide to implementation in antimicrobial resistance surveillance sites, World Health Organization (2016) available at http://www.who.int/antimicrobial-resistance/global-action-plan/surveillance/supporting-documents-tools/en/ or from the GLASS Secretariat glass@who.int

2. Steps in setting up a national AMR surveillance system

The *GLASS Manual* outlines ten proposed steps in setting up a national AMR surveillance system - from the initial planning stage, through to monitoring and evaluating the surveillance system. Although the ten steps depict a certain logical order, actual implementation does not need to follow a strict sequential manner, depending instead on the specific country situation.

Step 1: Establish a National Coordinating Centre

A single officially-nominated national coordinating centre (NCC) is needed to oversee the entire national surveillance system and to ensure that the mechanisms for collaboration and communication among the different components function smoothly across the whole system.

The role of the NCC is frequently undertaken by a public health institute and is designated by the national authority that is responsible for human health, such as the Ministry of Health. However, other institutions such as research centres or universities, may be equally qualified to perform this role, and may be considered more suitable. The NCC should be capable of liaising with the other sectors to contribute to coordination of surveillance efforts across sectors, including data integration, analysis and reporting of AMR data from many different sources – human health, animal health, food and environment.

Currently harmonized integrated surveillance of AMR in humans, food-producing animals, environment and food is present in only a limited number of countries, but such an approach should be pursued by all countries.[5]

The NCC should identify a national focal point at the outset who will serve as the central point of contact within the NCC for all parts of the national surveillance system, as well as being responsible for developing links and mechanisms for collaboration with other entities both inside and outside of the country. The national focal point (NFP) will play a key role in facilitating collaboration and in ensuring channels of communication flow smoothly.

The NCC works closely with the national authority or coordination group that has the overall responsibility for implementing the national AMR strategy and national action plan on AMR. It will also need to engage the participation of other relevant stakeholders that may be able to contribute to surveillance efforts, such as the private health sector, if applicable.

The NCC should have first-hand experience in conducting and coordinating surveillance activities, and should have in-house epidemiological expertise. A defined structure for surveillance coordination and data management must be in place within the NCC, and the institution must be able and empowered to work in close collaboration with the national reference laboratory.

The internal structure and organizational make-up of the NCC will depend upon the national context and usual practice within each country.

[5] Antimicrobial Resistance Global Surveillance Report. World Health Organization (2014) available at http://apps.who.int/iris/bitstream/10665/112642/1/9789241564748_eng.pdf

The development of the NCC activities should be done in close collaboration with the NRL, and supported by a multidisciplinary team. The multidisciplinary team should comprise professionals with expertise in surveillance, epidemiology, infectious diseases, clinical microbiology, and data management, and can include professionals from within and/or outside the institution.

Step 2: Define the surveillance objectives

The objectives for the national AMR surveillance programme are defined by the NCC, in collaboration with the national authority responsible for coordinating the national strategy and action plan on AMR, all relevant public health authorities and the national reference laboratory.

The objectives should be relevant, realistic and implementable and should be driven by three main considerations:

- the country's specific public health priorities
- the initial assessment of the AMR situation in the country, and
- the goals and objectives as defined in the overall national strategy to tackle AMR.

The surveillance system will also need to inform and promote global efforts as outlined in the *GLASS Manual*.

Specific pathogens, pathogen-antibiotic combinations and resistance patterns and mechanisms that are of particular concern and relevance to the country, should be considered for inclusion in the national AMR surveillance system.

GLASS has defined a set of indicators regarding eight human pathogens and four specimens to measure progress in global surveillance in the early implementation phase. However, each country will need to establish its own set of indicators that are of direct relevance to the country's national public health priorities. When reporting to GLASS, a country should address those indicators that are common to both GLASS and the national surveillance system (please see the *GLASS Manual* for detailed information on GLASS AMR priority pathogen and pathogen-antibiotic combinations).

It is also important that the national AMR surveillance system is able to capture and highlight unusual types of resistance that fall outside of the defined set of pathogen-antibiotic combinations. The national reference laboratory, in consultation with the NCC, will therefore need to state which additional isolates should be sent from the laboratories serving AMR surveillance sites to the NRL for further testing and confirmation of unusual types of AMR.

Step 3: Define a strategy for gradual implementation

Once a country has assessed its needs and resources, established the NCC and defined its surveillance objectives and targets, a strategy can be developed for the gradual implementation of the national surveillance system and its participation in GLASS.

Each country will need to set its own strategy that will map out the details of the incremental steps to be taken. This will be based on the existing capacities in the country that could support a national

surveillance system, and the pace with which it can establish the core components and start conducting surveillance activities.

The NCC should ensure that both core and support functions are put in place to assure the quality of the surveillance system from the outset. [6,7]

The NCC should estimate the start-up and ongoing costs of the national surveillance system, taking into consideration any resources that are already available at existing structures. A surveillance system that is built upon existing structures may require less additional resources and may be more sustainable.

Issues to consider for the gradual implementation of the strategy include:

- costs – availability of resources to set up and maintain AMR surveillance
- feasibility – how likely it is that the system as it is proposed can be implemented given current in-country capacities and resources.

Countries with limited resources may consider starting an AMR surveillance system that is based on:

- one or a small number of AMR indicators;
- one or a small number of surveillance sites;
- establishing one national reference laboratory; and
- less time- and resource-consuming surveillance strategies.

The AMR indicators chosen may be, for instance, the most relevant and easily implementable indicators that can be collected by surveillance sites and whose quality is assured on clinical, microbiological and epidemiological grounds. These limited indicators could be one or a small number of pathogens from one or a small number of specimens. Additional indicators may be added gradually to the national surveillance system.

At the outset, countries may choose one or a small number of surveillance sites that have laboratories with good laboratory practice, clinical services, and whenever possible, epidemiological infrastructure. The clinical laboratories should have access to a quality assurance scheme (e.g. facilitated by the national reference laboratory). After an initial implementation phase, once the surveillance sites are functioning as per the proposed protocols, other sites may be added, learning from experiences at the initial site(s).

The country may also wish to start with less time- and resource-consuming surveillance approaches, while still being able to gather information to guide empiric treatment and national strategies. Continuous surveillance may provide more accurate measures on trends, but it may also prove to be very challenging to sustain throughout the year, particularly when starting out in a limited resource setting. Instead, countries may opt to start with surveillance performed periodically, over a limited

[6] Communicable disease surveillance and response systems: A guide to planning. World Health Organization (2006) available at http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_LYO_2006_1.pdf

[7] Communicable disease surveillance and response systems: A guide to monitoring and evaluation. World Health Organization (2006) available at http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_LYO_2006_2.pdf

time period (e.g. 3 months). Another less time- and resource-consuming approach is continuous surveillance of a certain type of disease or group of patients (see Box 4 for example).

Box 4: **Example of a country setting-up a national AMR surveillance system**

Country A decides to start conducting national surveillance by collecting information only on AMR in diarrhoeal diseases as these diseases are a significant health concern for the country. Initial reports indicate that *Salmonella spp*. are the primary cause of diarrhoeal disease and so, **Country A** chooses to look specifically at resistance in *Salmonella spp*. against the most commonly used antimicrobial medicines for severe infections in Country A i.e. ciprofloxacin and ceftriaxone.

Country A selects one District Hospital (150 beds for in-patients) and one Health Centre (20 beds for in-patients) to participate as surveillance sites. The rationale for the choice of these two facilities is based on the fact that both are already served by a microbiology laboratory that participates in the quality assurance scheme overseen by the national reference laboratory. In addition, assessment of these sites has demonstrated that they have sufficient personnel, equipment and regular supply of consumables to perform the necessary surveillance activities. Furthermore, the senior management of both facilities has confirmed support to participate in the surveillance system.

The NCC in **Country A** organizes training for staff at the two facilities on issues related to AMR surveillance as follows:

- Diagnostic stewardship - Clinicians are instructed on when and how to: request laboratory tests, collect specimens, forward specimens with appropriate identification and with patient information fully completed, to the microbiology laboratory.
- Specimen testing - Laboratory technicians are trained in relevant laboratory procedures and on how to manage the patient results, including results validation and prompt reporting to clinicians and surveillance officers. Refresher training is provided regularly.
- Data entry using the software defined by NCC - A data entry officer/surveillance officer is trained to enter all results from all specimens tested, including patient information and microbiological results (both negative and positive results). If the facility does not have an epidemiologist to support data management, analysis and reporting, the data entry officer/surveillance officer should be responsible for the data flow to the NCC.

Step 4: Establish a national reference laboratory

All national AMR surveillance systems need access to at least one national reference laboratory (NRL) to provide overall laboratory expertise and guidance. The NRL should be participating in an internationally recognized quality assurance scheme and should ideally be accredited.

Some countries may have several national reference laboratories, specializing in specific diseases or pathogens. Other countries may need to build up their laboratory capacity in order to have a fully functioning NRL in the country. In all cases, however, a single laboratory should be designated to serve as the national AMR reference laboratory for the whole country and to perform the main tasks required in order to maintain and support the national AMR surveillance system. In some circumstances, where no laboratory capacity currently exists in the country, regional collaboration may be an option whereby a neighbouring country's NRL can fulfil this role.

In some circumstances, the NRL may be located within the same institution as the NCC. In this event, careful consideration is needed to clearly distinguish between their respective functions and ensure that each is able to fulfil its responsibilities independently.

The overall role of the NRL is to promote and facilitate good laboratory practice at the country level and to promote the harmonization of methodology and standards used, such as the European Committee on Antimicrobial Susceptibility Testing (EUCAST) or the Clinical and Laboratory Standards Institute (CLSI) guidelines. These standards should be implemented across the entire national surveillance system, in line with the recommendations of the *GLASS Manual*.

A quality assurance system ensures reliability and reproducibility of laboratory data. The NRL should organize or facilitate the participation of all laboratories at AMR surveillance sites in an EQA scheme. This will help to monitor the gradual improvement in the capacities of the laboratories and the reliability of the data provided. Furthermore, transparent discussion of national EQA results will encourage laboratories to improve their performance and processes.

The NRL must also have the capacity and capability to perform confirmatory testing such as verification of species identification and AST, including minimum inhibitory concentration (MIC) determination. The NRL will need to validate the microbiological data provided by local surveillance sites in close collaboration with the NCC. Ideally, the NRL should have the capacity to perform or have -when in-house capacity is not yet developed- access to specialized tests such as molecular detection of resistance mechanisms.

NRLs are encouraged to participate in international workshops on AST and molecular techniques. These workshops can provide an opportunity for enhanced training and sharing of experiences between countries. NRL staff members would also benefit from exchanges and on-site training at national reference laboratories located in other countries with well-established national AMR surveillance networks or other centres of excellence in the field of AMR.

Step 5: Develop or adapt national protocols

National surveillance protocols should be based on the needs and available resources in the country. It is the responsibility of the NCC to oversee the development and updating of protocols in close collaboration with all respective stakeholders. The *GLASS Manual* provides a set of the surveillance

indicators and metrics to be followed by participating countries, but the indicators are limited to a number of pathogens and specimens. Countries should not be limited by GLASS indicators, and each country should define the indicators that are most relevant for its purposes. Specific protocols and accompanying tools and documents should be adapted by the NCC from the *GLASS Manual* and related documents and resources to reflect the national context. Subjects to cover could include:

- data collection
- laboratory protocols
- diagnostic stewardship
- data flow.

It is the responsibility of the NRL to lead on adapting and regularly updating standards for laboratory processes, including AST standards. The NRL should also ensure that these standards are being implemented across the national system and provide guidance and technical support in quality management where needed.

Step 6: Identify AMR surveillance sites

AMR surveillance sites are the front line of the surveillance system. In addition to their clinical role in diagnosing and treating patients, they should have access to epidemiological support and a microbiology laboratory.

Participating sites are selected by the NCC. When selecting a potential AMR surveillance site, the following criteria should be considered:

- support from the central and local management, and the motivation of local staff to participate in surveillance, to comply with case definitions and protocols for collecting specimens, and to generate the necessary clinical, demographic and epidemiological data;
- availability of and accessibility to a laboratory with the capacity and capability to perform microbiological diagnostic testing, adequate staffing levels, equipment and a reliable supply chain;
- logistical feasibility to routinely collect and transport clinical specimens;
- ability to manage and report surveillance data, including denominator data (e.g. specimens submitted for testing);
- capacity and support to connect to the national network and report data to NCC;
- relative cost efficiency of conducting surveillance activities compared with other possible sites;
- sufficient number of patients and volume of laboratory diagnostic activity to allow a meaningful analysis of surveillance data;
- ability to mentor and support capacity building at subsequent sites;
- demographic, socioeconomic and geographic representativeness;
- representation of different levels of health care.

Each AMR surveillance site will determine its own internal organization. However, every surveillance site should be able to gather and report microbiological and patient information data for surveillance purposes.

Successful AMR surveillance activities at the site depend on team work among:

- clinical team – to collect patient samples and to forward them together with the correct patient information;
- laboratory team – to handle and process the samples appropriately and to provide timely, relevant and meaningful results to both the clinical staff and the surveillance team; and
- surveillance team – to perform epidemiological and data management functions and to consolidate data.

The long-term sustainability of the programme depends on available and appropriate levels of resources for surveillance activities, including data management that is ideally supported by an electronic information system.

The staff at the AMR surveillance site should be actively promoting and be committed to diagnostic stewardship and should have the full support of the administration and management to conduct AMR surveillance in a manner that is consistent with the needs of the national surveillance system, as well as GLASS. The NCC, with support from the NRL and relevant stakeholders, facilitates the implementation and monitoring of diagnostic stewardship (see Box 5) activities at surveillance sites. A tool to support implementation of diagnostic stewardship at surveillance sites has been developed.

Internal quality control (IQC) should be a routine procedure undertaken by participating laboratories to ensure quality of testing. IQC should cover all diagnostic tests and procedures including isolation and identification of pathogen and antimicrobial susceptibility testing. IQC should also cover media production and equipment maintenance.

It is recommended that the NCC enrols AMR surveillance sites in a gradual or stepwise manner to learn from the experience of each before expanding the combination of pathogens/types of specimens and coverage. For example, at the outset the national surveillance system may be targeting only one pathogen/specimen, and at only one surveillance site. The optimal number of participating AMR surveillance sites will depend on the country context, and no single algorithm exists to determine the appropriate number. The range of participating sites should aim for representative population coverage, should include both in- and outpatient facilities and should be from both the public and private sector, if applicable. The overriding important factor when selecting a surveillance site is the institutional commitment to undertake and sustain surveillance, thereby ensuring the long term collection and reporting of good quality data.

The data are reported to the NCC in line with the requirements of the national AMR surveillance strategy as well as GLASS standards. Data compilation for local use may be done at the AMR surveillance site itself or with the support of the NCC. Ideally, data management on site and data reporting to the NCC is facilitated electronically, and should use the software defined by the NCC.[8]

[8] The WHONET software has been adapted to facilitate AMR surveillance data collection in line with GLASS standards. Available at www.who.int/antimicrobial-resistance/global-action-plan/surveillance/glass-resources/en or at http://www.whonet.org/software.html.

Each surveillance site should have a designated surveillance team, including clinical, infection prevention and control, and microbiology staff and, if present, a surveillance officer (epidemiologist). The team should have a designated focal point who is responsible for liaising with the NCC and for coordinating surveillance activities at the site.

The scope of work of the surveillance team could include:

- developing and disseminating local guidelines and standard operating procedures (SOPs);
- implementing a diagnostic stewardship programme to encourage appropriate use of microbiological diagnostics in guiding therapeutic decisions, and informing local empiric treatment recommendations and AMR control strategies;
- reviewing and overseeing training needs and activities on site:
    - clinical staff to select, collect and submit specimens and provide clinical data
    - laboratory staff to promote good laboratory practice, to isolate and identify pathogens, to perform antimicrobial susceptibility testing according to standards and to report microbiological results from tested specimens
    - surveillance staff to compile demographic, clinical, microbiological and epidemiological information derived from clinical specimens (both negative and positive results);
- ensuring access to appropriate epidemiological support;
- establishing and strengthening data management capacity, including data validation process;
- generating regular surveillance reports for local purposes (e.g. stratified by participating departments/wards, if applicable) and the national AMR surveillance system.

The AMR surveillance team should also have close links to the infection prevention and control team, the drug/antibiotic committee and the diagnostic stewardship team, where applicable. It is advisable to implement a coordination mechanism for regular meetings and exchange between these teams at each surveillance site to ensure continuous and effective collaboration.

Box 5: Diagnostic stewardship

The quality of surveillance based on routine data can be improved by diagnostic stewardship, which is an integral part of both patient management and standardized surveillance. Clinicians must have timely, systematic guidance and training in conducting relevant diagnostic activities in order to minimize bias caused by variations in how patient samples are sent for microbiological analysis. Clinicians should provide standardized core patient data accompanying every sample sent for AST.

Microbiological results derived from the application of the diagnostic stewardship concept will support clinicians in the diagnosis of infectious disease syndromes and in choosing the best available therapeutic option. Diagnostic stewardship promotes safe patient care, responsible use of antimicrobial medicines, and provides accurate and representative AMR surveillance data to inform empiric treatment guidelines and AMR control strategies. Important steps and elements of diagnostic stewardship implementation are described elsewhere.[9]

Step 7: Disseminate protocols and tools and train staff in their use

It is the responsibility of the NCC to disseminate protocols and to develop tools for implementation at all levels of the national system. The NCC and NRL, in close collaboration with other relevant stakeholders, such as medical societies and training institutions, should support the development/adaptation of local SOPs and guidelines, and training activities.

The NCC should develop and roll out a training programme for all staff involved in AMR surveillance activities, addressing topics related to each specific area of responsibility, including data management.

The NRL should take the lead on the laboratory aspects of the training needs; e. g. organize regular in-country training for participating laboratories in quality management and microbiological diagnostics, including standards for antimicrobial susceptibility testing. These training workshops together with regular communication between the NRL and participating laboratories should aim to ensure that standards are updated and communicated in a timely fashion.

An initial assessment can help to identify the training needs for the different categories of surveillance staff (epidemiology, laboratory and clinical staff) at different levels, from which a comprehensive training plan and schedule can be drawn up. The implementation of the training plan and the proportion of surveillance staff that receive training in different aspects of surveillance, including data management (validation process, data completeness, etc.) should be monitored against a pre-determined set of indicators.

[9] Diagnostic stewardship: A guide to implementation in antimicrobial resistance surveillance sites. World Health Organization (2016) available at http://www.who.int/antimicrobial-resistance/global-action-plan/surveillance/supporting-documents-tools/en/ or from the GLASS Secretariat glass@who.int

Several tools have been developed to support the implementation of national AMR surveillance systems and their participation in GLASS.[10] Further training in specific areas, such as data management or diagnostic stewardship, may be required, subject to the needs and available resources of each individual country.

Step 8: Start collecting data on progress or status of implementation and on AMR

GLASS collects two distinct types of data from countries: i) progress in implementing a national AMR surveillance system in the country and ii) data on resistance detected in the priority pathogen-antibacterial combinations as described in the *GLASS Manual*.

A GLASS implementation questionnaire has been developed to capture important information from countries that can track progress in implementation globally. [11]

It is the responsibility of the NCC to coordinate AMR data collection from the surveillance sites and to compile the data into a central AMR surveillance database. The NCC also hosts and manages the central AMR surveillance database and ensures data validation at the national level. The data validation process refers to any process, manual or automated, that is used to flag inaccurate, incomplete or unreasonable data. This can be done by means of format checks, completeness checks, or application of valid limit checks (e.g. the system would not accept a negative value for age).

AMR surveillance sites can use WHONET software, which has a feature to combine data files from one or more surveillance sites and to aggregate the data into the GLASS format, or another compatible software already in use, to upload and report data electronically to the NCC.

If one or more AMR surveillance sites are unable to support electronic data submission, the NCC should make paper forms available for their use. It should then be the responsibility of the NCC to enter the data directly into the central database (WHONET or other software) using the information provided on the paper forms. Participating surveillance sites should keep a record of all submitted data and maintain standard records on AMR data.

Step 9: Report information on the AMR situation

The NCC should define the period of the year when a call for data submission from surveillance sites to the national level will be issued. If the country reports data to international networks and/or GLASS, it is advisable to schedule the active national data call to take into consideration the data call periods of international networks and GLASS in order to allow sufficient time for data collection and validation at the national level before international reporting. This would provide sufficient time to develop the national report, as well as to meet the deadline for international and global reporting.

[10] Implementation tools available at http://www.who.int/antimicrobial-resistance/global-action-plan/surveillance/glass/en/ or from the GLASS Secretariat glass@who.int

[11] GLASS implementation questionnaire and A guide to completing the GLASS implementation questionnaire available at http://www.who.int/antimicrobial-resistance/global-action-plan/surveillance/supporting-documents-tools/en/ or from the GLASS Secretariat glass@who.int

Surveillance sites should be asked to validate and approve submitted data before they are included in national reports and published.

Individual patient/specimen data should be de-duplicated and validated, as outlined in the *GLASS Manual*. The specifications for data aggregation including more detailed information on de-duplication are available and can be implemented in other software systems.[12] WHONET software[13] has a feature that enables electronic data files from several surveillance sites to be combined and to be aggregated for submission to the GLASS IT platform. A WHONET manual for use primarily by the national data manager has been developed for this purpose. A schematic view of data flow is provided in the *GLASS Manual* as well as examples of different metrics that are generated by GLASS. A protocol "How to use the GLASS IT platform" with detailed information on aggregated data submission to and data management in the GLASS IT platform gives a detailed explanation on the process, including data validation and report features for users.[14]

The NCC reports aggregated data to GLASS and will also produce a report on a regular basis on the AMR data submitted from participating surveillance sites. The NCC report should include the metrics that are reflecting the country's needs and that are specified in the *GLASS Manual*. The report should also describe the methodology, interpret the results and draw conclusions.

The NCC will need to draw up a dissemination strategy for the national AMR data. This may include both web-based and printed reports that can be distributed to targeted professionals, such as hospital managers, heads of antibiotic or drug committees and heads of infection prevention and control committees. It is anticipated that these professionals will use these data in routine daily practice as well as in presentations at scientific and professional meetings.

Particular attention should also be given to communicating and discussing AMR surveillance information with the national authority responsible for coordinating the national surveillance strategy and national action plan on AMR.

Information on the AMR situation will inform the national strategy and aggregated data reported to GLASS will inform regional and global strategies.

Step 10: Monitoring and evaluation

Monitoring and evaluation is an important element of all surveillance systems and is integral in ensuring that the surveillance objectives are being achieved and that planned activities are on track. Ideally, an M&E framework should include pilot testing of any revised approach to surveillance, in addition to reviewing implementation steps and adjusting the process as necessary.

Establishing a framework for M&E of the national AMR surveillance system implementation will help countries to develop and improve their national surveillance systems and facilitate their capacity to participate in GLASS. It is of particular value to countries with limited resources that are aiming to

[12] A guide to preparing aggregated AMR data files available at http://www.who.int/antimicrobial-resistance/global-action-plan/surveillance/supporting-documents-tools/en/ or from the GLASS Secretariat glass@who.int

[13] Available at www.who.int/antimicrobial-resistance/global-action-plan/surveillance/glass-resources/en or at http://www.whonet.org/software.html.

[14] A guide to uploading aggregated AMR data available at http://www.who.int/antimicrobial-resistance/global-action-plan/surveillance/supporting-documents-tools/en/ or from the GLASS Secretariat glass@who.int

build their surveillance capacities. More importantly, M&E should help to detect issues that may be having a negative impact on the success of the surveillance system, allowing recommendations for timely adjustments to be made.

The process of M&E provides planners with an overview of progress within the programme, from the baseline situation, through to the extent to which programme objectives are being achieved. Establishing the M&E process at the outset of the national AMR surveillance system implementation encourages planners and implementers to define realistic objectives that are in line with the overall goal of putting in place a sustainable system. In the human health sector, medical societies, institutions doing clinical research on AMR, medical schools and training institutions may all be important stakeholders that could assist in the development, implementation and monitoring of the national AMR surveillance system.

A national surveillance system comprises several elements that a country might choose to target for development, monitoring and evaluation.[15] These elements include:

- the overall structure, including the three core components of a national AMR surveillance system (i.e. the NCC, at least one NRL, and designated surveillance sites);
- defined public health priorities for AMR surveillance, such as priority pathogens and infections corresponding to the surveillance objectives;
- core functions and quality of the surveillance system, including case detection, data collection, analysis, and reporting; and
- support functions of the system that facilitate implementation of the core functions and include standards, guidelines and training.

In order to achieve the desired outcomes, the programme will need resources (inputs) and will need to develop activities (process) that will lead to results (outputs) that will bring about the achievement of the desired outcomes. Indicators should be identified to measure each of these elements.

A series of sample indicators has been developed that are appropriate for monitoring the elements listed above. These are laid out in Annex 1. The framework outlined in Annex 1 groups the indicators according to the metric above and provides potential measures of verification from the perspective of national-level planners. Planners should decide on a strategy to apply the monitoring indicators to evolve according to the development of the surveillance system. For instance, the country may choose to apply a tiered approach, selecting only those indicators that apply at different stages of development of the system.

[15] Guide to monitoring and evaluating communicable disease surveillance and response systems. World Health Organization (2006) available at http://www.who.int/csr/resources/publications/surveillance/WHO_CDS_EPR_LYO_2006_2.pdf

Figure 2: Steps in monitoring and evaluation of the implementation of a national AMR surveillance system

STEPS	EXAMPLES
PLANNING (baseline)	• Situation analysis (what has already been done and what is known about AMR surveillance in the country), resources and needs assessment conducted
INPUT (needed resources)	• Funding for personnel, equipment, consumables • Local guidelines and SOPs • Staff with expertise in the field of AMR surveillance • Communication protocols and facilities
PROCESS (activities)	• Mobilization and management of funds • Development or adaptation of SOPs • Development and implementation of training materials • Agreed means and frequency of communication between clinical laboratory and surveillance staff
OUTPUT (results)	• Sustainable financing and resources available on regular basis • Common understanding of protocols • Trained staff with relevant competencies at surveillance sites • Information on defined AMR public health priorities available
OUTCOME	• National strategy informed by national AMR surveillance

Annex 1. Sample indicators for M&E of national AMR surveillance systems participating in GLASS to be used at national level

N	Indicator	Definition	Type	Value (national level)	Comment
Surveillance structure					
1	Presence of a National Coordinating Centre (NCC)	A NCC with mandate, ToRs and responsible person (focal point) is established	Input	NCC established (Y/N)	
2	NCC with the mandate for sharing information with GLASS	Mandate to participate in GLASS has been delegated by the relevant national authority	Input	NCC mandate includes sharing aggregated data (Y/N)	The mandate includes sharing aggregated data with WHO.
3	National plan for AMR surveillance	Presence of a strategic and operational plan for implementing and strengthening AMR surveillance, including participation in GLASS	Input	National plan exists (Y/N)	
4	Presence of a National Focal Point (NFP)	NFP is designated and communicating with GLASS	Input	National GLASS focal point designated (Y/N)	
5	Budget for AMR surveillance	There is an identified national budget to support the national AMR surveillance system	Input	National budget for AMR surveillance programme (Y/N)	
6	National Reference Laboratory (NRL)	At least one NRL is designated with agreed terms of reference to support national AMR surveillance system	Input	NRL for AMR designated (Y/N)	If the capacity is not yet within the country, collaboration established with appropriate NRL abroad

N	Indicator	Definition	Type	Value (national level)	Comment
7	Number of AMR surveillance sites	Number of surveillance sites fulfilling requirements to collect and report data on patients and AST that can feed into the national system	Input	# of targeted sites established (n of N)	The requirements to be met are described in section 6.
8	Existence of documented roles & responsibilities	Roles and responsibilities are well- documented at each level of surveillance system	Process	Documentation of roles (national, intermediate, peripheral, community) exists (Y/N)	
9	Collaboration of sectors other than human health in the national surveillance system to support intersectoral collaboration, networking and partnership	Existence of intersectoral collaboration, networking and partnerships with other sectors (animal health, agriculture, water and sanitation, etc.) with regular meetings	Process	Regular intersectoral partner meetings take place at relevant level (national, intermediate, peripheral) (Y/N)	
10	Functional network of surveillance sites	Existence of a network of functional surveillance sites established, including regular exchange of information and experience.	Process	Regular <establish frequency> reports generated and sent to national level	Functional network of surveillance sites is defined as an established mode of communication among surveillance sites participating in the national surveillance system, including regular meetings and shared access to information/data from all sites.
Public health priorities targeted for surveillance					
11	Priority specimen types included in the AMR surveillance	Number of prioritized specimen types included in the national targets	Output	% of surveillance sites with n out of N national target specimens included	
	Surveillance sites performing blood cultures	Number of surveillance sites performing blood cultures	Output	% of surveillance sites with n out of N national target blood specimen included	
	Surveillance sites performing urine cultures	Number of surveillance sites performing urine cultures	Output	% of surveillance sites with n out of N national target urine specimen included	
	Surveillance sites performing …	Number of surveillance sites performing…			

N	Indicator	Definition	Type	Value (national level)	Comment
12	Priority pathogens	Number of prioritized pathogens in the national targets	Output	% of surveillance sites with n out of N national targets included	
13	Priority pathogen-antimicrobial combinations	Number of prioritized pathogen-antimicrobial combinations in national targets	Output	% of surveillance sites with n out of N national targets included	
14	Priority pathogen-antimicrobial combinations	Number of prioritized pathogen-antimicrobial combinations in GLASS targets	Output	% of surveillance sites with n out of N GLASS targets included	
Core functions & Quality of Surveillance					
15	Surveillance sites with standard case definition	Proportion of surveillance sites (i.e. health facilities) with standard case definitions for AMR episodes to be reported regularly in the surveillance system	Input	% of sites using standard case definitions (at national, sub-national level)	
16	Completeness of data reported	Proportion of surveillance reports with no missing required information	Output	% of surveillance sites submitting complete reports to surveillance system	
17	Timeliness of submission of surveillance reports	Proportion of surveillance sites that submitted surveillance reports to the next higher level on time	Output	% of surveillance sites submitting reports to national system on time	
18	Routine validation of surveillance data	Existence of the routine validation of surveillance data at the national level and at the surveillance sites	Process	% of surveillance sites with established routine validation of surveillance data	
19	Existence of regular feedback	Presence of a feedback mechanism between surveillance sites and the next higher level (e.g. regional or national level)	Process	Feedback mechanism in place between surveillance sites and higher level (Y/N)	
20	National strategy informed by AMR surveillance	National body in charge of national strategy to contain AMR receives information on AMR rates and progress of implementation of surveillance system at least 1x/year and discusses implications for national strategy	Outcome	Discussion mechanism in place at the national body in charge of national action plan (Y/N)	

N	Indicator	Definition	Type	Value (national level)	Comment
21	Capacity to detect and notify unusual AMR events	Inclusion of unusual AMR events in the surveillance system and reported to the local surveillance sites for confirmation and action	Process	% of unusual AMR events appropriately notified at national, intermediate, peripheral levels	GLASS will be providing a suggested list of AMR profiles considered as “unusual AMR events”. Countries should decide to use these and then add unusual resistance according to their situation. Besides detecting unusual resistance this also frequently identifies errors and is therefore an important quality indicator.
22	Confirmation of unusual type of AMR	Capacity to confirm unusual type of AMR either within the laboratory or at a reference laboratory	Process	% of laboratories with capacity to confirm unusual events at national, intermediate and peripheral levels	
23	Mechanism for AMR outbreak detection within hospitals	Ability to detect and notify potential AMR outbreaks in hospital as part of the national AMR surveillance system	Process	% of surveillance sites with the capacity to detect and notify potential AMR outbreaks to the NCC	This is a complex task and countries may consider this indicator in later, more developed stages of the surveillance system development.
24	National laboratory QA programme	National laboratory internal QA programme organized and implemented in all laboratories providing data to the national system, covering pathogen isolation, identification and AST	Process	% of laboratories with QA programme implemented	
25	External quality assurance system (EQA)	The national AMR programme organizes and runs EQA for all laboratories participating in the national system, covering pathogen isolation, identification and AST	Process	% of laboratories participating in EQA	
26	NRL participation in EQA	The NRL participates in an internationally recognized EQA organized or supported by a regional reference laboratory or network	Process	NRL participates in an EQA (Y/N)	
27	EQA performance of laboratories contributing data to the national system	Proportion of laboratories contributing data to the national system passing the EQA proficiency test in the reporting period	Process	% of sites passing EQA PT	

N	Indicator	Definition	Type	Value (national level)	Comment
Support functions (guidelines and training)					
28	AMR surveillance standards and guidelines	Availability of AMR surveillance standards and guidelines in line with the GLASS manual	Input	% of surveillance sites applying national AMR surveillance standards and guidelines in line with the GLASS manual	Including specimen and epidemiological data collection, referral, identification, AST etc.
29	Availability of good communication lines	Proportion of surveillance sites with functional communication facilities (telephone, email, internet)	Input	Y/N national level, % surveillance sites	
30	Availability of budget line for surveillance activities at national and local levels	Evidence of a budget line for surveillance activities (human resources, reporting forms, feedback bulletins, communication, supervision, training, etc.)	Input	Y/N national level, % surveillance sites	
31	Surveillance staff trained in AMR surveillance	Training of surveillance staff in AMR surveillance including GLASS methodology	Process	# of scheduled training sessions conducted % of staff with appropriate training in AMR surveillance	"trained staff" implies initial and regular/continuous training
32	Clinical staff trained in AMR surveillance	Training of clinical staff in AMR surveillance including GLASS methodology	Process	# of scheduled training sessions conducted % of staff with appropriate training in AMR surveillance	"trained staff" implies initial and regular/continuous training
33	Laboratory personnel trained in AMR surveillance and laboratory techniques	Training of laboratory personnel in AMR surveillance and laboratory techniques according to GLASS requirements	Process	# of scheduled training sessions conducted % of staff with appropriate training in AMR surveillance	"trained staff" implies initial and regular/continuous training
34	Supervision conducted at surveillance sites	Proportion of surveillance sites with supervision conducted	Process	Supervision mechanism in place (Y/N), % surveillance sites	