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Systematic review of surveillance systems for AMR in Africa

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Aims: Surveillance is a useful tool for tracking antimicrobial resistance (AMR) trends, patterns, therapeutic and policy interventions. Proper correlation of surveillance data gives meaningful insight into the underlying epidemiology and facilitates development of rational interventions. This comprehensive review aims to identify, classify and assess gaps in Global Antimicrobial Resistance and Use Surveillance System (GLASS) reporting and national action plan (NAP) implementation in Africa.

Methods: Articles published in English were searched across five electronic databases (PubMed, Scopus, Embase, AJOL and Cochrane) and grey literature. Articles were screened against inclusion/exclusion criteria and data from eligible studies were retrieved and analysed. This systematic review was registered in the International Prospective Register of Systematic Reviews (PROSPERO) on 31 July 2020 under protocol CRD42020192165.

Results: Of the 4304 records found, only 32 met the initial inclusion criteria (4 peer reviews and 28 were grey literature). From these records, 41 surveillance systems were identified (30 national and 11 transnational). After final review of reported outcomes, only 23 national surveillance systems met the inclusion criteria. Indicators recorded from these systems shows lack of external quality assessment (EQA) in some systems and limited reporting of parameters such as infection origin, patient population and pathogen types.

Conclusions: The outcome of the review shows that although AMR surveillance has been implemented in 23 out of the 47 countries in the region, a number of limitations exist in the surveillance methods and reporting protocols that can impair the usefulness, validity and trustworthiness of data generated from these surveillance systems.

Background

Surveillance is an invaluable tool for monitoring trends and patterns, as well as effects of therapeutic and policy interventions. Surveillance by itself must be conducted in a systematic manner in order to provide outcome-specific data needed for planning, implementation, evaluation and tackling of public health challenges like antimicrobial resistance (AMR).[1] AMR is a global health challenge, which requires continuous surveillance; however, poor or lack of surveillance activities in many low- and medium-income countries (LMICs) creates a situation that impairs containment efforts.[2–4] In Africa, understanding the full extent and impact of AMR is hampered by poor continent-wide AMR surveillance data.[5] Country data, when available, are not routinely collected and not frequently shared with or recognized by national bodies, which limits their ability to influence national actions.[6] In recognition of this negligence, the 68th World Health Assembly (WHA) endorsed a Global Action Plan (GAP) to tackle AMR with an overarching goal to draw national and global attention to AMR.[7] The GAP proposed a set of objectives, of which the first two focus on awareness and understanding of AMR through surveillance and research.

Despite the GAP policy recommendation for development of national action plans (NAPs) and continuous surveillance of priority pathogens, a desktop analysis published in 2017 assessing uptake of this policy in the African region revealed that only two countries had NAPs for AMR and none had any form of national surveillance.[8] It is projected that if unaddressed, the mortality rate due to AMR could rise to 10 million annually by 2050.[9,10] As such, routine surveillance is a priority, especially in LMICs

and in Africa where the burden of AMR is anticipated to be the highest.[11,12]

Although current evidence indicates increasing surveillance in the African region,[13] these surveillance systems have not been mapped and their methods of collecting and reporting surveillance data have not been assessed for adequate collection of parameters to help estimate burden of disease caused by AMR. These parameters are crucial for identifying patterns of resistance, patient needs, instituting treatment guidelines, and monitoring the effectiveness of containment efforts. Surveillance system assessment is important as surveillance generally is often characterized by heterogeneity in scope, objectives, methodology and reporting across different geographical locations despite efforts for harmonization. Although characteristics that are important to one system may be less important to another, it is recommended that emphasis be placed on harmonization of surveillance approach, particularly at a regional level.[14] Hence, ensuring that the elements required for driving containment efforts are captured and correlated with demographic data for the patient populations from whom the pathogens were isolated forms the bases for reliable data and a key priority for surveillance systems.[15] Information on surveillance systems in Africa are generally lacking, thus one system cannot leverage on the success of another for surveillance improvement. In addition, without understanding the differences in surveillance methodologies and data collection processes, making recommendations, monitoring the effectiveness of a surveillance system and estimating morbidity and mortality figures at a regional level can be grossly hampered. The Global Antimicrobial Resistance and Use Surveillance System (GLASS) exists to bridge these gaps by highlighting important parameters that will ensure data-driven action on AMR and also serves as a global platform for aggregation of surveillance data. To our knowledge, it is not clear whether these systems provide appropriate descriptions of methodology and quality assessment of data, which are crucial to the adequate interpretation of surveillance information. With the view of informing future capacity building in AMR surveillance in Africa, the overarching goal of this study was to systematically review approaches to AMR surveillance and identify gaps in data reporting and compliance with GLASS and GAP recommendations.

Methods

This systematic review followed the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA 2020) reporting checklist.[16]

Eligibility criteria

Eligibility was limited to surveillance systems in the 47 countries under the WHO African region. An AMR surveillance system in this review is defined as a structured and systematic process that collects data on the prevalence or incidence cases of AMR, performed continuously or periodically, with a defined methodology and specified performance indicators that can be used to monitor progress.

Inclusion criteria

We included surveillance systems with identifiable and available methodology, scope and design. We also included systems that are endorsed by: institutions; regional, national or transnational health organizations; scientific societies; or academic bodies. To further meet the inclusion criteria, the system must provide data on a periodic basis and report surveillance data for at least 6 months, on at least one of the following GLASS priority pathogen isolates from humans (*Acinetobacter* spp., *Escherichia coli*, *Neisseria gonorrhoeae*, *Salmonella* spp., *Klebsiella pneumoniae*, *Shigella* spp., *Staphylococcus aureus*, *Streptococcus pneumoniae*).[4] To be eligible for inclusion, the surveillance system must be based on one of the following surveillance approaches: active, passive, laboratory-based, population-sentinel, targeted population-based surveillance for specific pathogen, sector-specific, integrated One Health approach and community-based. As the review was focused on surveillance of pathogens isolated from humans, articles reporting AMR in both adult, geriatric and paediatric patient populations were all included. To meet the general inclusion criteria, literature must have been written in English language, on one or more of the WHO African countries, reported at least one of the review outcomes (surveillance system attributes, surveillance scope, surveillance method, GLASS activity and NAP implementation) and be of relevance to the primary objective of this review.

Exclusion criteria

This review excluded: surveillance activities and systems from animals, environment and food; studies on epidemiological, morphological or cellular analysis; systems that are inactive; articles on antimicrobial susceptibility pattern; studies related to aggregate resistance rates or total bacterial isolates; articles reporting surveillance of TB, malaria and HIV; surveillance beyond Africa and non-English publications. Also excluded were articles without available full texts. All publications were individually reviewed and those not meeting the pre-defined inclusion criteria were excluded from the final articles for analysis.

Information sources

Two reviewers conducted independent searches of five electronic databases (Cochrane, PubMed, Embase, Scopus and AJOL). All databases were systematically searched from inception up until December 2021. Publication on all types of patient populations written in English language were identified and retrieved. To identify institutional, regional, national or transnational literature or prints on surveillance systems and country self-assessment questionnaire for AMR in Africa, a comprehensive grey literature search was also conducted. These included: Google Scholar; websites of WHO, institutes of public health, countries and ministries; Africa Centre for Disease Prevention and Control (ACDC), Africa Society of Laboratory Medicine (ASLM) and Nigerian Centre for Disease Control (NCDC) (searched between November and December 2021). The inclusion of grey literature was to ensure this review exhausted available literature and further reduced the impact of publication bias associated with systematic reviews using only published peer-reviewed papers.[17–19] Lastly, a secondary search of the bibliography of each of the retrieved articles meeting the inclusion criteria were manually checked for additional eligible documents that could have been missed during the database and grey literature search.

Search strategy

The search strategy was developed by O.J.O. with assistance of faculty librarians at the University of the West of England, Bristol, UK. Search terms were derived from the population, intervention, comparison, outcome (PICO) elements shown in Table S1, available as Supplementary data at *JAC* Online.[20,21] Corresponding subject-related synonyms for each keyword were identified and used to build the search strings. The search strategy that was used for the database search is available in Table S2. The search string was primarily developed on PubMed with applicable Boolean operators before translating to other databases using database-specific controlled vocabulary. The medical subject heading (MeSH) terms

were equally applied to help retrieve results relevant to the research domain. Filters were applied across the database to retrieve articles in the English language only; this is due to the cost and time involved in procuring translating software or hiring professional translators. Limits were also applied to retrieve articles on human populations. For the grey literature search, the websites of all identified organizations and countries were searched using the internal website search function to locate relevant materials. In addition, we searched Google for each country utilizing the following combination of keywords in English to extract relevant data from publicly available resources: 'Antimicrobial resistance' AND/OR 'national action plan' AND/OR 'Surveillance systems' AND 'country'.

Selection process

A total of 4302 articles were retrieved and downloaded into a comma-separated values (CSV) file before exporting to DistillerSR v2 (DSR) software for screening. DSR is web-based systematic review software developed by Evidence Partners, which follows an intuitive five-step process and allows for uploading of references, creation of screening forms, assignment of reviewers, monitoring of project progress, and exporting of data. The software was set up to assign a unique reference ID to each uploaded article for ease of de-duplication, full-text retrieval and reference tracking. The imported documents were first checked for duplicates, and identified duplicates were quarantined before commencement of screening using the software workflow, which was set up to perform level 1 to 5 screening. The embedded screening form for each level was adapted to reflect the study specifics. Two independent reviewers (O.J.O. and U.I.) performed a two-step initial selection process involving: level 1 (rapid title) screening of all the retrieved documents and exclusion of non-relevant documents; and level 2 (detailed abstract) screening against defined inclusion criteria for all relevant documents (both reviewers were blinded for this level). Conflicts were resolved after level 2 screening by consensus before progressing to level 3. The full text of potentially eligible documents was obtained and assessed for reporting relevant outcome, and documents not meeting the general eligibility criteria were excluded. Figure 1 shows the flow chart for the screening steps and article selection process.

Data collection process

The embedded data extraction tool in the DSR was adapted to the specifics of the review and was used to manually extract all required data. The tool extracted information on NAP progress, GLASS participation and surveillance system on a country-by-country basis. The data collected for each country included: surveillance field (human only), NAP development, NAP programme timeline, surveillance approach, surveillance activity, establishment of a reference laboratory and GLASS enrolment. For the surveillance systems, data on testing method, sources of data, reporting standard, frequency of reporting, provision of external quality assurance (EQA), targeted population, representativeness, standardization of procedures, and pathogen type were collected. Surveillance systems were generally grouped under: national, transnational, regional or institutional. Data were aggregated at the level of countries and surveillance systems. Data collection was performed by two reviewers (O.J.O. and U.I.) and discrepancies were resolved by consensus.

Outcomes

The main outcomes for this review are based on the surveillance system attributes as outlined in the ECDC guidelines for evaluating public health surveillance systems, which includes data quality, sensitivity, representativeness, acceptability, efficiency, effectiveness and timeliness.[15] Due to limitation of data, this review outcome will focus on representativeness, data quality and timeliness. In addition, NAP development and implementation, GLASS enrolment and surveillance reporting were reported as secondary outcomes.

Intervention

Surveillance is the only intervention for this study and it was classified according to (1) approach, including laboratory-based, sentinel, population-based and sector-specific surveillance, integrated One Health approach and community-based surveillance; and (2) category, including national, subnational, transnational, regional or institutional.

Risk-of-bias assessment

All literature meeting the inclusion criteria were grouped under two categories (peer reviewed and non-peer reviewed/grey literature) to facilitate appropriate quality checks. All grey literature, including national, regional, transnational, organizational, assessments, evaluation or policy reports, were appraised using the authority, accuracy, coverage, objectivity, date, significance (AACODS) checklist, which provides six criteria for critiquing grey literature.[22] For all questions, a 'yes' is assigned if the study meets all the criteria, 'partly' if the study largely meets the criterion but differs in some important aspect, 'no' if the study deviates substantively from the criterion, 'unclear' if the report provides insufficient information to judge whether the study complies with the criterion and 'NA' (not applicable) if the criterion is not relevant in a particular instance.

For peer-reviewed articles, the Joanna Briggs Institute (JBI) checklist for systematic review was used to assess the methodological quality of all systematic reviews included in this study. Responses ranging from yes, no, unclear or not applicable were assigned to individual questions in accordance with evidence presented in the study.[23] Lastly, the JBI checklist for qualitative research was also used to assess literature that included qualitative and mixed-method studies.[24,25] These checklists were generally used to assess the methodological quality of relevant studies and to determine the extent to which a study has addressed the possibility of bias in its design, conduct and analysis. The risk-of-bias assessment was carried out by two reviewers (O.J.O. and U.I.) and discrepancies were resolved by consensus. The included studies and critical appraisal checklist are presented in Table 1, while links to all studies are available in Table S3.

Data analysis

Data synthesis involved collating and summarizing results in tabular form to reflect country progress on the development and implementation of NAPs, AMR surveillance activities, and characteristics of each surveillance system, which includes type of surveillance activities, isolate source, patient population and quality assessments. Frequency of distributions, expressed as percentage (%), was calculated for each variable and displayed graphically. Analysis was stratified by country, surveillance system and attributes. The review followed the synthesis without meta-analysis (SWiM) guidelines for the synthesis and reporting of findings extracted from included studies.[26]

Results

Description of study selection

Of the initial 4304 records retrieved from electronic database and grey literature searches, 667 duplicates were identified and quarantined by the DSR. The remaining 3637 records passed through two-level screening for title and abstract, after which a further 3561 articles were excluded for not meeting the inclusion criteria. These were articles on AMR surveillance in animals and the environment, studies on surveillance for HIV, TB and malaria, studies on susceptibility pattern, studies on characterization of infection,

Table 1. List of included studies (characteristics and critical appraisal)

Study number	Authors (date)	Title	Study design	Main objective	Setting	Quality assessment tool used
1	Seale *et al.*, 2017	Supporting surveillance capacity for AMR: laboratory capacity strengthening for drug resistance infection in low and middle income countries	Desk-based analysis, Focus group discussion, Observational	To map and compare existing models and surveillance systems for AMR, to examine what worked and what did not work.	Ethiopia, Malawi	JBI
2	Jimah and Ogunseitan, 2020	National action plan on antimicrobial resistance: stakeholders analysis on implementation in Ghana	Qualitative interviews	To better understand stakeholder's perspective on the implementation and sustainability of the NAP.	Ghana	JBI
3	Hazim *et al.*, 2018	Establishment of a sentinel laboratory-based AMR surveillance network in Ethiopia	Situational analysis	To describe how laboratory-based AMR surveillance was implemented in Ethiopia including challenges and lessons learned to help guide successful AMR surveillance in other settings.	Ethiopia	AACODS
4	WHO (GLASS), 2021	Global Antimicrobial Resistance and use Surveillance report	Implementation status of national AMR surveillance systems	To describe countries' activities in relation to AMR surveillance systems.	AFRO region	AACODS
5	WHO (GLASS), 2020	Global Antimicrobial Resistance and use Surveillance report	Early implementation summary report	To describe countries' activities in relation to AMR surveillance systems.	Cote d'Ivoire, Ethiopia, Gambia, Kenya, Liberia, Madagascar, Mali, Mauritius, Mozambique, Nigeria, South Africa, Uganda, United Republic of Tanzania, Zambia, Zimbabwe	AACODS
6	WHO (GLASS), 2019	Global Antimicrobial Resistance and use Surveillance report	Early implementation summary report	To describe countries' activities in relation to AMR surveillance systems.	Ethiopia, Gambia, Kenya, Liberia, Madagascar, Malawi, Mali, Mauritius, Mozambique, Nigeria, South Africa, Uganda, Zambia, Zimbabwe	AACODS
7	WHO (GLASS), 2018	Global Antimicrobial Resistance and use Surveillance report	Early implementation summary report	To describe countries' activities in relation to AMR surveillance systems.	Kenya, Madagascar, Malawi, Mozambique, Nigeria, South Africa, Uganda, Zambia, Zimbabwe	AACODS
8	WHO, 2017–20	Joint external evaluation (JEE) of International health regulations (IHR) core capabilities	Mission evaluation report	To assess country capacities and capabilities relevant to the 19 technical areas of the JEE and provide data to inform current strengths, areas for improvement and priority actions.	AFRO region	AACODS

9	FAO, OIE and WHO, 2021	The Tripartite Antimicrobial Resistance (AMR) Country Self-assessment Survey (TrACSS) report	Self-assessment questionnaire	Report of country progress in the implementation of NAPs.	AFRO region	AACODS
10	FAO, OIE and WHO, 2020	The Tripartite Antimicrobial Resistance (AMR) Country Self-assessment Survey (TrACSS) report	Self-assessment questionnaire	Report of country progress in the implementation of NAPs.	AFRO region	AACODS
11	FAO, OIE and WHO, 2019	The Tripartite Antimicrobial Resistance (AMR) Country Self-assessment Survey (TrACSS) report	Self-assessment questionnaire	Report of country progress in the implementation of NAPs.	AFRO region	AACODS
12	FAO, OIE and WHO, 2018	The Tripartite Antimicrobial Resistance (AMR) Country Self-assessment Survey (TrACSS) report	Self-assessment questionnaire	Report of the second round of results of AMR country self-assessment survey.	AFRO region	AACODS
13	FAO, OIE and WHO, 2017	The Tripartite Antimicrobial Resistance (AMR) Country Self-assessment Survey (TrACSS) report	Self-assessment questionnaire	To monitor country progress in the implementation of NAPs.	AFRO region	AACODS
14	Ogyu *et al.*, 2020	National action plan to combat AMR: a One-Health approach to assess policy priorities in action plans	Quantitative analysis	To systematically categorize, describe and quantify useful information about AMR policies and content of NAPs.	AFRO region	JBI
15	WHO, 2014	Global action plan on antimicrobial resistance	Policy guide	Manual for developing NAPs.	Trans-regional	AACODS
16	NAP, 2021	National action plan antimicrobial resistance	Strategic plan	Tackling AMR.	Eritrea	AACODS
17	NAP, 2018	National action plan antimicrobial resistance containment strategy	Strategic plan	Implementation plan.	Eswatini	AACODS
18	NAP, 2015	The national action plan on antimicrobial resistance	Strategic plan	To address actions needed to be taken in order to combat AMR in the country.	Ethiopia	AACODS
19	NAP, 2017	The national action plan on antimicrobial resistance	Strategic plan	To summarize the structure for the development and implementation of the NAP.	Ghana	AACODS
20	NAP, 2017	The national action plan on antimicrobial resistance	Strategic plan	A national strategic plan to address AMR in human, animal, crops, food safety and environmental aspects.	Kenya	AACODS
21	NAP, 2018	The national action plan on antimicrobial resistance	Strategic plan	To address actions needed to be taken in order to combat AMR in the country.	Liberia	AACODS
22	NAP, 2017	The national action plan on antimicrobial resistance	Strategic plan	A national strategic plan to address	Malawi	AACODS

Continued

Table 1. *Continued*

Study number	Authors (date)	Title	Study design	Main objective	Setting	Quality assessment tool used
				AMR in human, animal, crops, food safety and environmental aspects		
23	NAP, 2017	The national action plan on antimicrobial resistance	Strategic plan	To address actions needed to be taken in order to combat AMR in the country.	Mauritius	AACODS
24	NAP, 2017	Namibian antimicrobial resistance action plan	Strategic plan	Action plan for AMR.	Namibia	AACODS
25	NAP, 2017	The national action plan on antimicrobial resistance	Strategic plan	A national strategic plan to address AMR in human, animal, crops, food safety and environmental aspects.	Nigeria	AACODS
26	NAP, 2020	National action plan on antimicrobial resistance	Strategic plan	Combating AMR.	Rwanda	AACODS
27	NAP, 2018	National strategic plan for combating antimicrobial resistance	Strategic plan	Tackling AMR.	Sierra Leone	AACODS
28	NAP, 2014	The national action plan on antimicrobial resistance	Strategic plan	To summarize the structure for the development and implementation of the NAP.	South Africa	AACODS
29	NAP, 2018	The national action plan on antimicrobial resistance	Strategic plan	To summarize the structure for the development and implementation of the NAP.	Uganda	AACODS
30	NAP, 2017	The national action plan on antimicrobial resistance	Strategic plan	To address actions needed to be taken in order to combat AMR in the country.	United Republic of Tanzania	AACODS
31	NAP, 2017	The national action plan on antimicrobial resistance	Strategic plan	To summarize the structure for the development and implementation of the NAP.	Zambia	AACODS
32	NAP, 2017	The national action plan on antimicrobial resistance	Strategic plan	A national strategic plan to address AMR in human, animal, crops, food safety and environmental aspects.	Zimbabwe	AACODS

Reference lists and links for included studies are available in Table S1. AFRO region, WHO African region.

morphological studies and studies on the burden of AMR. Only the full texts of 76 records that met the eligibility criteria were retrieved and fully reviewed. An additional 49 records were removed after full-text review for not reporting at least one of the review outcomes, which include country progress, surveillance system attribute, surveillance scope, surveillance method or any specified performance indicators that can be used to monitor progress. A further five records were identified after a secondary search of reference tables of included articles. A total of 32 articles met the overall inclusion criteria and were considered in this synthesis. A detailed presentation of the article selection process is summarized in the PRISMA flow chart (Figure 1).

Characteristics of included studies

Of the 32 fully reviewed records, 4 records were published peer-reviewed journals and 28 records were retrieved from grey sources. The grey literature records comprised four GLASS reports, one Joint External Evaluation (JEE) of International Health Regulations (IHR) core capabilities, five Tripartite Antimicrobial Resistance Country Self-assessment Survey (TrACSS) reports on monitoring progress on addressing AMR, one WHO GAP policy guide and 17 NAPs. Detailed information of included study characteristics is available in Table 1.

NAPs

Data revealed that countries within the region are at various stages with the development and implementation of their NAPs. NAP development and implementation is progressive albeit gradual. The majority of the African countries have developed a NAP for AMR. Currently, thirty-five (74.5%) countries of the 47 WHO African region have developed/implemented NAP for AMR, five (10.6%) countries have their action plans undergoing development and in seven (14.9%) countries, no information regarding NAP development status for AMR was reported. Figure 2 shows trends in development and implementation of NAPs over the 5 years of GAP launch in the region. Of the 35 NAPs detected, only 19 were publicly available. After review against eligibility criteria, only 17 NAPs met the inclusion criteria. These are NAPs that have been published, are publicly available and written in English. NAPs for the rest of the countries could not be assessed. Data collected also showed that NAP implementation indicators are not commensurate with NAP development despite reports of implementation and funding. Indicators such as presence of a National Reference Laboratory (NRL), National Coordinating Centres (NCC), sentinel sites and functional laboratories were not reported to be operational in all the NAPs reviewed. Of the 17 NAPs assessed, only 13 (76.5%) countries reported to have established an NRL. In terms of surveillance activity for AMR, varying levels of activities were recorded: four (23.5%) countries reported having functioning national AMR surveillance covering common bacterial infections in hospitalized and community patients, with EQA; one (5.9%) country reported conducting surveillance at sentinel sites for some pathogens of public health importance; five (29.4%) countries reported having a national AMR surveillance system that integrates surveillance of AMR across sectors, and generates regular reports covering at least one common indicator; three (17.6%) countries reported AMR data are collated locally for common bacteria, but data collection may not use a standardized approach and lacks national coordination and/or quality management; one (5.9%) country reported presence of laboratories with technical capacity for AMR detection/reporting; one (5.9%) country reported sentinel sites for AMR surveillance have been identified in the human health sector to increase geographical coverage; and two (11.8%) countries reported no capacity for generating AMR data. In terms of approach to tackling AMR, 10 (58.8%) countries reported using a multisectoral approach, one (5.9%) country reported use of a One Health approach, four (23.5%) countries reported joint working, and two (11.8%) countries reported that no formal multisectoral governance or coordination mechanism on AMR exists. Table 2 shows the 17 NAPs assessed and their implementation indicators in line with GAP objectives.

Country-level surveillance systems for AMR

Thirty surveillance systems were initially detected from the 47 countries in the WHO African region. After review of available information regarding these surveillance systems, six surveillance systems were excluded for not reporting surveillance data, one system was excluded for reporting antimicrobial consumption (AMC) surveillance data only. Only 23 systems met the inclusion criteria and these are systems in place for routine AMR surveillance and data collection. All systems were identified as national surveillance. Table 3 shows the general features of these surveillance systems for which data were extracted. Data show the population pool from these surveillance systems are generally from laboratories, hospitals, outpatient and inpatient sources. All systems also reported AMR data collection from patients of all ages though the actual patient ages were not reported. Fourteen (60.9%) systems reported frequency of reporting as yearly, four (17.4%) systems reported frequency as pooled, and five (21.7%) reported both yearly and pooled. The technical level of data management of the laboratory network in the AMR surveillance systems also vary: five (21.7%) systems reported most laboratories of the network use computers to manage part of their data but important improvements in the system are required; four (17.4%) systems reported some minor improvements are required in some laboratories of the network to improve computerized management of AMR laboratory data; six (26.1%) systems reported antimicrobial susceptibility testing (AST) data are handled manually, or AST data management is not computerized in all laboratories of the network and/or there are problems in the recording of the samples and their traceability along the analysis chain; and eight (34.8%) systems did not report the technical level of data management.

These surveillance systems also feature specific characteristics, which are reported in Table 4. The report shows that South Africa had the highest number of surveillance sites, totalling 737, while Gambia and Mozambique had the least with a single site each. The testing method is consistent across all systems. Twenty-two (95.7%) systems reported use of AST as standard, only one (4.3%) system reported the use of both AST and WGS. EQA is provided to the majority of the NRLs affiliated to these surveillance systems. Of the 23 surveillance systems assessed, 19 (82.6%) systems reported provision of EQA to the NRLs; four (17.4%) systems reported no provision of EQA to the NRL. Of the 19 systems providing EQA to their NRL, only eight (42.1%)

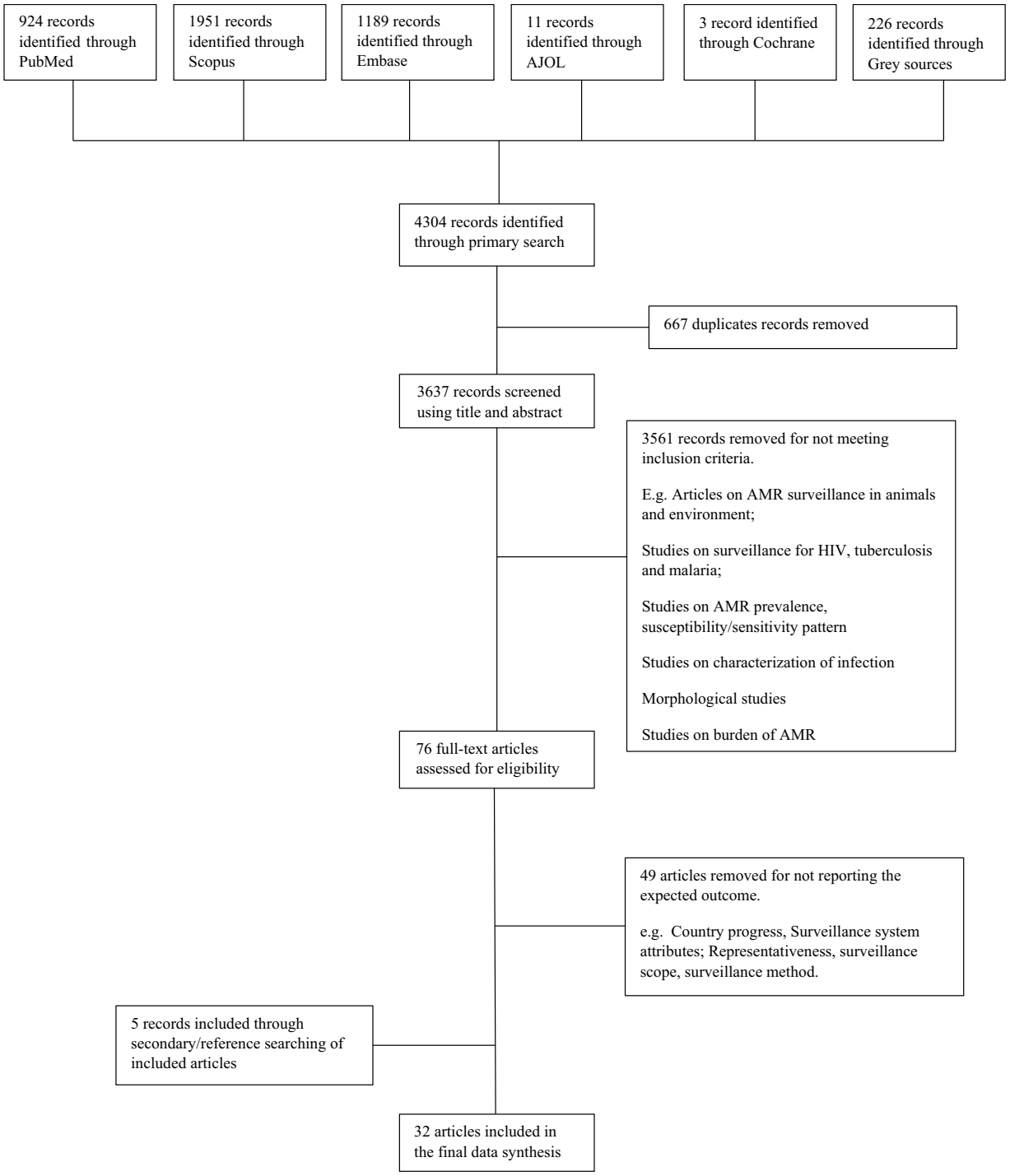

Figure 1. PRISMA flow chart showing screening steps of articles retrieved from database and grey literature search.

systems reported provision of EQA to all other local laboratories performing AST for AMR surveillance; two (10.5%) reported provision of EQA to some laboratories performing AST for AMR surveillance; and nine (47.4%) systems do not provide EQA to non-reference laboratories that perform and report AST for AMR surveillance to national networks. For all 23 surveillance systems that were assessed, a record of the use of AST interpretation criteria was available for 16 systems; among these, the CLSI breakpoint was used in 12 (75%) countries; the EUCAST breakpoint was used as reference in 1 (6.3%) country; in 3 (18.7%) countries, some laboratories use CLSI and others use EUCAST. Only 18 systems reported the level of standardization and

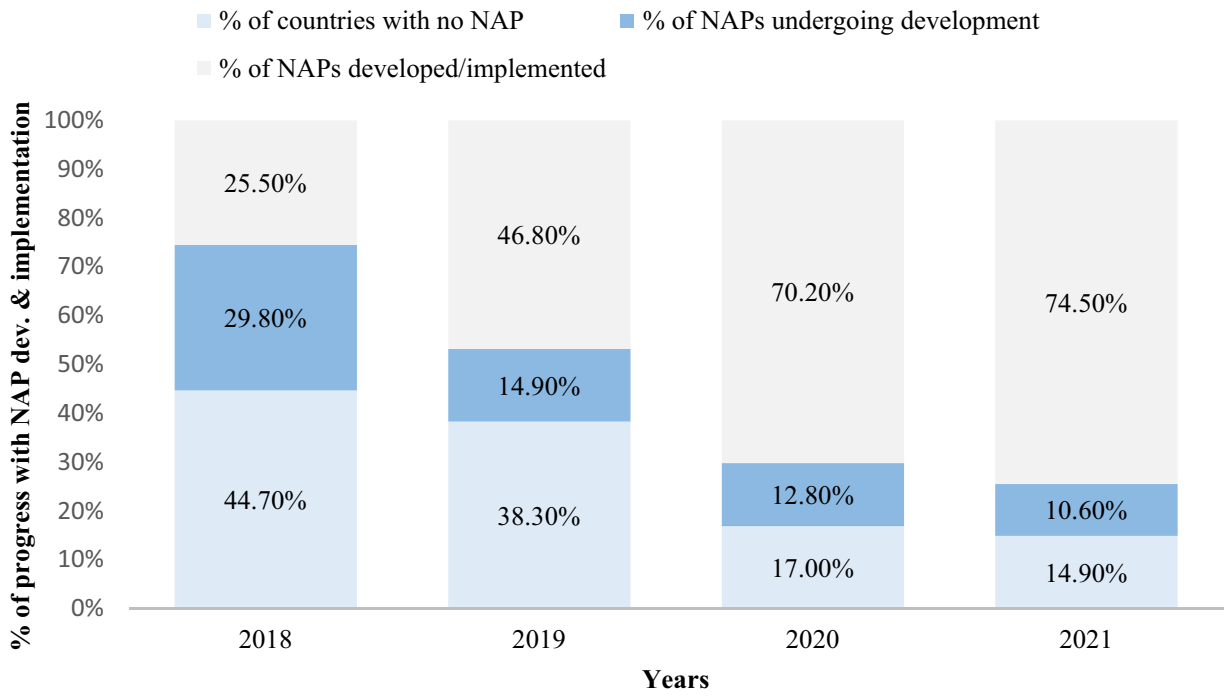

Figure 2. Trends in development and implementation of NAPs in the region for the period reviewed. This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

harmonization of procedures among laboratories included in the AMR surveillance system; the other 5 systems did not record this information. Of the 18 systems reporting this indicator, 3 (16.7%) reported 100% of their laboratories use the same AST guidelines; two (11.1%) systems reported between 80% and <100% of laboratories use the same AST guidelines; 4 (22.2%) reported between 30% and 79% of laboratories follow the same AST guidelines; and 9 (50%) reported no standardized national AST guidelines are in place or less than 30% laboratories follow the same AST guidelines.

Transnational surveillance systems for AMR

In addition to the national surveillance systems, 11 transnational surveillance systems were also detected. These surveillance systems are supported by government and institutional funding, some by pharmaceutical companies like Pfizer, GSK, Merck and Co, and other organizations like the Bill & Melinda Gates Foundation (BMGF), WHO and CDC. These systems collect data on a wide range of pathogens including *Enterococcus* spp., *Staphylococcus* spp., *Klebsiella*, *Acinetobacter* spp., *Pseudomonas* spp. and *Enterobacter* spp. (the ESKAPE pathogens). Some of these systems have been conducting surveillance since before the WHO GAP and GLASS launch but their operational scopes were not available, hence their exclusion for not meeting the inclusion criteria. Table 5 shows features of these surveillance systems that were excluded from the review.

Enrolment and data reporting to GLASS

Countries are gradually responding to invitation for enrolment and calls for data reporting from GLASS (a network that collects data on global AMR surveillance). Of the 47 African countries that were reviewed, only 10 (21.3%) countries were enrolled on the GLASS network at the 2018 report; this number increased to 15 (31.9%) countries in 2019 and then to 19 (40.4%) and 30 (63.8%) countries at the 2020 and 2021 reports, respectively. Following the same trend, surveillance data reporting to GLASS recorded a gradual increase at the various calls for data submission. Of the 47 African countries that were reviewed, nine (19.1%) countries reported surveillance data during the first call; this number increased to 14 (29.8%) countries at the second call and then to 15 (31.9%) countries at both the third and fourth calls. Figure 3 shows the increasing trend of country enrolment and surveillance data reporting to GLASS for the period reviewed. The number of sites reporting surveillance data to GLASS also rapidly increased over the GAP period of operation. Figure 4 shows the trend in increase of surveillance sites from only 35 sites in 2018 to 251 sites in 2021. Analysis of data collected from surveillance systems reporting to GLASS shows some surveillance parameters were either underreported or completely missing. Table 4 shows that data on the number of tested patients was only reported in five (21.7%) systems, while infection origin was reported in four (17.4%) systems. Figure 5 shows the percentage of systems reporting some of these required surveillance indicators. It shows infection origin as the least reported indicator whereas pathogen type is the most reported.

Discussion

The most important findings from this systematic review of AMR surveillance systems in Africa are: (a) there is evidence of

Table 2. Status of NAP development and implementation indicators in the region

Country	Progress with development of action plan on AMR	Timeline	Multisector/One Health approach	Surveillance activity for AMR	NRL	Reporting to GLASS
Eritrea	NAP developed	2021–25	Multisectoral working group(s) or coordination committee on AMR established with government leadership.	AMR data collated locally for common bacteria, but data collection may not use a standardized approach and lacks national coordination and/or quality management.	Not established	No
Eswatini	NAP developed	2021–25	Multisectoral working group(s) or coordination committee on AMR established with government leadership.	National AMR surveillance activities for common bacterial infections follow national standards, and an NRL that participates in EQA.	Established	No
Ethiopia	National AMR action plan approved by government that reflects GAP objectives, with a budgeted operational plan and monitoring arrangements.	2015–20	Multisectoral working group(s) is (are) functional, with clear terms of reference, regular meetings, and funding for working group(s) with activities and reporting/accountability arrangements defined.	There is a functioning national AMR surveillance system covering common bacterial infections in hospitalized and community patients, with EQA, and an NCC producing reports on AMR.	Established	Yes
Ghana	National AMR action plan has funding sources identified, is being implemented, and has relevant sectors involved with a defined monitoring and evaluation process in place.	2017–21	Joint working on issues including agreement on common objectives.	National AMR surveillance activities for common bacterial infections follow national standards, and an NRL that participates in EQA.	Established	Yes
Kenya	National AMR action plan approved by government that reflects GAP objectives, with a budgeted operational plan and monitoring arrangements.	2017–20	Joint working on issues including agreement on common objectives.	There is a functioning national AMR surveillance system covering common bacterial infections in hospitalized and community patients, with EQA, and an NCC producing reports on AMR.	Established	Yes
Liberia	National AMR action plan has funding sources identified, is being implemented, and has relevant sectors involved with a defined monitoring and evaluation process in place.	2018–22	Multisectoral working group(s) or coordination committee on AMR established with government leadership.	AMR data collated locally for common bacteria, but data collection may not use a standardized approach and lacks national coordination and/or quality management.	Established	Yes
Mauritius	NAP developed	2017–21	No formal multisectoral governance or coordination mechanism on AMR exists.	There are laboratories that have the technical capacity for antimicrobial detection/reporting.	Established	Yes
Malawi	NAP developed, approved and launched	2017–22	No formal multisectoral governance or coordination mechanism on AMR exists.	No capacity for generating data (antibiotic susceptibility testing and accompanying clinical and epidemiological data) and reporting on antibiotic resistance.	Not established	No

Namibia	NAP developed	2017–22	Multisectoral working group(s) or coordination committee on AMR established with government leadership.	National AMR surveillance activities for common bacterial infections follow national standards, and an NRL that participates in EQA.	Established	No
Nigeria	National AMR action plan approved by government that reflects GAP objectives, with a budgeted operational plan and monitoring arrangements.	2017–22	Multisectoral working group(s) is (are) functional, with clear terms of reference, regular meetings, and funding for working group(s) with activities and reporting/accountability arrangements defined.	National AMR surveillance activities for common bacterial infections follow national standards, and an NRL that participates in EQA.	Established	Yes
Rwanda	NAP developed	2020–24	Multisectoral working group(s) or coordination committee on AMR established with government leadership.	AMR data collated locally for common bacteria, but data collection may not use a standardized approach and lacks national coordination and/or quality management.	No information	No
Sierra Leone	NAP developed	2018–22	Multisectoral working group(s) or coordination committee on AMR established with government leadership.	No capacity for generating data (antibiotic susceptibility testing and accompanying clinical and epidemiological data) and reporting on antibiotic resistance.	Not established	No
South Africa	NAP developed	2014–24	Joint working on issues including agreement on common objectives	There is a functioning national AMR surveillance system covering common bacterial infections in hospitalized and community patients, with EQA, and an NCC producing reports on AMR.	Established	Yes
Uganda	NAP developed	2018–23	Functional multisectoral working group.	AMR surveillance sentinel sites have been identified in the human health sector to increase geographical coverage.	Established	Yes
United Republic of Tanzania	National AMR action plan has funding sources identified, is being implemented, and has relevant sectors involved with a defined monitoring and evaluation process in place.	2017–22	Joint working on issues including agreement on common objectives.	There is a functioning national AMR surveillance system covering common bacterial infections in hospitalized and community patients, with EQA, and an NCC producing reports on AMR.	Established	Yes
Zambia	National AMR action plan approved by government that reflects GAP objectives, with a budgeted operational plan and monitoring arrangements.	2017–27	Multisectoral working group(s) is (are) functional, with clear terms of reference, regular meetings, and funding for working group(s) with activities and reporting/accountability arrangements defined.	There is a functioning national AMR surveillance system covering common bacterial infections in hospitalized and community patients, with EQA, and an NCC producing reports on AMR.	Established	Yes
Zimbabwe	NAP developed	2017–21	One Health.	Sentinel sites are conducting surveillance of some pathogens of public health importance.	Established	Yes

Table 3. General features of AMR surveillance systems identified and classified according to study criteria

Country	Surveillance coverage	Focus/ scope	Targeted population	Reported age group	Frequency of reporting	Technical level of data management of the laboratory network in the AMR surveillance system	Pathogens reported					
							Acinetobacter spp.	*E. coli*	*K. pneumoniae*	*Salmonella* spp.	*S. aureus*	*S. pneumoniae*
Algeria	National	AMR	Hospitals and outpatients	All ages	Yearly	Most laboratories of the network use computers to manage part of their data but important improvements in the system are required.	✓	✓	x	x	x	x
Burundi	National	AMR	Hospitals in/ outpatients	All ages	Pooled	AST data are handled manually, or AST data management is not computerized in all laboratories of the network and/or there are problems in the recording of the samples and their traceability along the analysis chain.	x	✓	x	✓	x	x
Cameroon	National	AMR	Hospitals	All ages	Yearly	Not reported	x	✓	x	✓	x	✓
Chad	National	AMR	Hospitals	All ages	Yearly	AST data are handled manually, or AST data management is not computerized in all laboratories of the network and/or there are problems in the recording of the samples and their traceability along the analysis chain.	x	x	x	✓	✓	x
Cote d'Ivoire	National	AMR	Hospitals	All ages	Yearly	Most laboratories of the network use computers to manage part of their data but important improvements in the system are required.	x	x	x	x	x	x
Ethiopia	National	AMR	Hospitals outpatients	All ages	Yearly/ pooled	Some minor improvements are required in some laboratories of the network to improve the computerized management of AMR laboratory data.	✓	✓	✓	x	✓	✓
Gabon	National	AMR	Laboratories	All ages	Yearly	Not reported.	x	✓	x	x	x	x
Gambia	National	AMR	Hospitals	All ages	Yearly/ Pooled	Not reported.	x	x	x	✓	x	✓
Ghana	National	AMR	Hospitals	All ages	Yearly	AST data are handled manually, or AST data management is not computerized in all laboratories of the network and/or there are problems in the recording of the samples and their traceability along the analysis chain.	x	✓	x	✓	x	x
Kenya	National	AMR	Hospitals Outpatients	All ages	Yearly/ pooled	Some minor improvements are required in some laboratories of the network to improve the computerized management of AMR laboratory data (sample input procedures, sample storage information, computerized transmission of data, etc.)	✓	x	x	✓	x	x

Liberia	National	AMR	Hospitals	All ages	Yearly/ pooled	AST data are handled manually, or AST data management is not computerized in all laboratories of the network and/or there are problems in the recording of the samples and their traceability along the analysis chain.	x		✓	x	x	x	x
Madagascar	National	AMR	Laboratories	All ages	Yearly	Most laboratories of the network use computers to manage part of their data but important improvements in the system are required.	✓		✓	✓	✓	✓	✓
Malawi	National	AMR	In/outpatient facilities	All ages	Pooled	Not reported.	✓		✓	✓	✓	✓	✓
Mali	National	AMR	Hospitals outpatients	All ages	Yearly	Some minor improvements are required in some laboratories of the network to improve the computerized management of AMR laboratory data.	✓		✓	✓	✓	✓	✓
Mauritania	National	AMR	Hospitals	All ages	Yearly	Not reported.	✓		x	x	x	x	✓
Mauritius	National	AMR	Hospitals	All ages	Pooled	AST data are handled manually, or AST data management is not computerized in all laboratories of the network and/or there are problems in the recording of the samples and their traceability along the analysis chain.	x		x	x	x	x	✓
Mozambique	National	AMR	Hospitals	All ages	Pooled	Not reported.	✓		✓	✓	✓	✓	✓
Nigeria	National	AMR	Inpatient and outpatient facilities	All ages	Yearly	Not reported.	✓		✓	✓	✓	✓	✓
South Africa	National	AMR	Hospitals and outpatient facilities	All ages	Yearly/ pooled	Most laboratories of the network use computers to manage part of their data but important improvements in the system are required.	✓		✓	✓	✓	✓	✓
Uganda	National	AMR	Hospitals and outpatient	All ages	Yearly	Not reported.	x		✓	✓	✓	✓	x
United Republic of Tanzania	National	AMR	Hospitals	All ages	Yearly	Most laboratories of the network use computers to manage part of their data but important improvements in the system are required.	x		x	✓	✓	✓	✓
Zambia	National	AMR	Inpatient and outpatient facilities	All ages	Yearly	Some minor improvements are required in some laboratories of the network to improve the computerized management of AMR laboratory data.	✓		✓	✓	✓	✓	x
Zimbabwe	National	AMR	Laboratories	All ages	Yearly	AST data are handled manually, or AST data management is not computerized in all laboratories of the network and/or there are problems in the recording of the samples and their traceability along the analysis chain.	x		x	✓	✓	x	✓

x, not reported; ✓, reported.

Table 4. Characteristics of included surveillance systems for AMR from the region

Country	Primary source of data	Number of surveillance sites	Testing method used	Resistance criteria/ reporting standard	Provision of EQA to local laboratories	Provision of EQA to NRL	Data on number of tested patients	Infection origin	Level of the standardization and harmonization of procedures among laboratories included in the AMR surveillance system
Algeria	Hospitals	Not reported	AST standard	Not reported	Not provided	Not provided	Not reported	Not reported	100% of laboratories use the same AST guidelines
Burundi	Hospitals laboratory	14	AST standard	CLSI	Not provided	Provided	Not reported	Not reported	Not reported
Cameroon	Hospitals	Not reported	AST standard	Not reported	Not provided	Not provided	Not reported	Not reported	No standardized national AST guidelines are in place or less than 30% of laboratories follow the same AST guidelines
Chad	Hospitals	Not reported	AST standard	Not reported	Not provided	Not provided	Not reported	Not reported	No standardized national AST guidelines are in place or less than 30% of laboratories follow the same AST guidelines
Cote d'Ivoire	Laboratory	52	AST standard	Not reported	Not provided	Not provided	Not reported	Not reported	No standardized national AST guidelines are in place or less than 30% of laboratories follow the same AST guidelines
Ethiopia	Laboratory	9	AST standard	CLSI	Provided to all labs	Provided	Not reported	Reported	Between 30% and 79% of laboratories follow the same AST guidelines
Gabon	NRL	2	AST standard	Not reported	Not provided	Provided	Not reported	Not reported	Not reported
Gambia	Laboratory	1	AST standard	CLSI	Not provided	Provided	Not reported	Not reported	Not reported
Ghana	Laboratory	Not reported	AST standard	Not reported	Provided to some labs	provided	Not reported	Not reported	No standardized national AST guidelines are in place or less than 30% of laboratories follow the same AST guidelines
Kenya	Laboratory	5	AST standard	CLSI	Provided to all labs	Provided	Not reported	Not reported	Between 80% and <100% of laboratories use the same AST guidelines
Liberia	Laboratory	3	AST standard	CLSI	Not provided	Provided	Not reported	Not reported	No standardized national AST guidelines are in place or less than 30% of laboratories follow the same AST guidelines
Madagascar	Laboratory	9	AST standard	EUCAST/CLSI	Not provided	Provided	Not reported	<70% reported	Between 30% and 79% of laboratories follow the same AST guidelines
Malawi	Laboratory	14	AST standard	EUCAST	Provided to all labs	Provided	<70% data reported	Not reported	Not reported
Mali	Laboratory	5	AST standard	EUCAST/CLSI	Provided to all labs	Provided	70%–100% reported	Not reported	100% of laboratories use the same AST guidelines
Mauritania	Laboratory	Not reported	AST standard	Not reported	Not provided	Provided	Not reported	Not reported	No standardized national AST guidelines are in place or less than 30% of laboratories follow the same AST guidelines
Mauritius	Laboratory	154	AST standard	CLSI	Not provided	Provided	Not reported	Not reported	No standardized national AST guidelines are in place or less than 30% of laboratories follow the same AST guidelines
Mozambique	Laboratory	1	AST standard	CLSI	Provided to all labs	Provided	70%–100% data reported	70%–100% data reported	Between 80% and <100% of laboratories use the same AST guidelines
Nigeria	Laboratory	29	AST standard	CLSI	Provided to some labs	Provided	Data not reported	<70% data reported	No standardized national AST guidelines are in place or less than 30% of laboratories follow the same AST guidelines
South Africa	Laboratory	737	AST standard/ WGS	EUCAST and CLSI	Provided to all labs	Provided	70%–100% data reported	Not reported	100% of laboratories use the same AST guidelines

Uganda	Laboratory	22	AST standard	CLSI	Provided to all labs	Provided	70%–100% reported	Not reported	Between 30% and 79% of laboratories follow the same AST guidelines
United Republic of Tanzania	Laboratory	63	AST standard	CLSI	Provided to all labs	Provided	Not reported	Not reported	No standardized national AST guidelines are in place or less than 30% of laboratories follow the same AST guidelines
Zambia	Laboratory	6	AST standard	CLSI	Not provided	Provided	No data reported	No data reported	Between 30% and 79% of laboratories follow the same AST guidelines
Zimbabwe	Hospitals and laboratories	5	AST standard	CLSI	Not provided	Provided	Not reported	Not reported	Not reported

development and implementation of NAPs; (b) the majority of the surveillance systems perform AST; (c) EQA is not routinely performed across participating laboratories; (d) some important surveillance parameters are not recorded; (e) information on incidence-based-indicators is generally lacking in all the systems; and (f) there is no tool for evaluating the effectiveness of surveillance systems for AMR. Data collected for this review suggest that surveillance activities for AMR are beginning to gain traction in the region, though levels of implementation still varies across the three core components of national AMR surveillance (NCC, NRL and sentinel surveillance sites). Surveillance expansion in the region is indicative of commitment on the part of governmental agencies and political will towards prioritizing policies aimed at addressing AMR. More countries are beginning to respond to AMR surveillance, which shows progress compared with previous reports.[8,27,28] This can be attributed to the recognition of the importance of AMR surveillance by WHO and the recommendations for development and implementation of NAPs for AMR.[29] As highlighted by the WHO GAP on AMR,[7] establishing efficient AMR surveillance begins with the development of a NAP that reflects the objectives of the GAP, and this is reflected in the data collected for this review. Despite the slow and gradual response, the number of countries with comprehensive NAPs that reflect the objectives of AMR surveillance have increased from only 1 country in 2014 to 35 countries recently. It is understandable that achieving AMR surveillance goes beyond NAP development but largely to implementation and finally translating to actual AMR surveillance. Though reports of NAP implementation, which is an important step towards establishing surveillance and AMR containment, are available, indicators that serve as evidence of NAP implementation are yet to be actioned in some systems. Whilst is it obvious that countries are yet to implement the full-scale actions that are proportionate to the AMR challenges faced by the region, tools that assess and monitor NAP implementation are required to identify strengths, challenges and gaps.

The region has also recorded an increase in the number of national surveillance activities compared with the pre-AMR GAP era where all identified AMR surveillance and related activities in the region were mainly transnational surveillance, Table 5. The presence of more AMR-focused surveillance systems in the region suggests that countries are beginning to recognize the importance of surveillance as a tool for tackling AMR, though major improvements are needed in data collection and reporting protocols, particularly as they relate to data quality and data completeness. Review of reporting documents shows some important surveillance parameters were missing in some systems and, when reported, are not sufficient to inform policy actions because they are often reported in isolation. There is poor representation of the number of infected patients, clinical infection, infection origin, specimens, sampling setting, population covered and demographic data (gender and age). Data incompleteness hugely undermines the ability of surveillance reports to fulfil the goal of surveillance, which is primarily to generate reliable results from which the most effective AMR control measures can be built. Observably, surveillance is expanding in the region but the mere existence of a surveillance system by itself does not guarantee provision of quality and representative data, and until these types of data are available, global estimate of the burden

Table 5. Transnational surveillance activities identified and classified according to the study criteria (general features and characteristics). These systems were excluded for non-availability of information on operational scope

Surveillance system	Countries	Website	Funding organization	Types	Year	Pathogens
Africa CDC Anti-Microbial Resistance Surveillance Network (AMRSNET)	All African countries	https://mail.africacdc.org/about/africa-cdc-antimicrobial-resistance-surveillance-network	Africa Union	Transnational	2018–ongoing	Unselected
Community-Based Surveillance of Antimicrobial Use and Resistance in Resource Constrained Settings Project Group	India, South Africa	https://doi.org/10.1111/j.1365-3156.2010.02695.x	USAID	Pilot project	2010	*S. pneumoniae*, *Haemophilus influenzae*
Global Antibiotic Resistance Partnership (GARP)	India, Kenya, Mozambique, Nepal, South Africa, Tanzania, United Republic of Uganda	https://cddep.org/projects/global-antibiotic-resistance-partnership/	BMGF	Academic	2008–ongoing	Unselected
The Gonococcal Antimicrobial Surveillance Programme (GASP)	WHO regions	https://www.who.int/data/gho/data/themes/topics/who-gonococcal-amr-surveillance-programme-who-gasp	WHO	Transregional	1992–ongoing	*N. gonorrhoeae*
International Network for the Study and Prevention of Emerging Antimicrobial Resistance	Cote d'Ivoire, Morocco, Senegal, Tunisia	https://wwwnc.cdc.gov/eid/article/7/2/70-0319_article	Public (CDC)	Academic	1998–2010	*Streptococcus* spp., *S. pneumoniae*, *Staphylococcus* spp., Enterobacteriaceae, *Neisseria meningitidis*, *Acinetobacter baumannii*, *Salmonella* Typhi, *H. influenzae*, *Brucella* spp., *Clostridium*
African-German StaphNet consortium	Tanzania, Gabon, Mozambique	https://doi.org/10.2217/fmb.12.126	Public (Deutsche Forschungsgemeinschaf)	Clinical study	2010–ongoing	*S. aureus*
Survey of Antibiotic Resistance (SOAR)	Democratic Republic of Congo, Senegal, Nigeria, Turkey, Egypt, South Africa, Morocco, Tunisia,	https://www.amrindustryalliance.org/case-study/gsks-survey-of-antibiotic-resistance-soar/	Pharma (GlaxoSmithKline)	Research	2002–ongoing	*S. pneumoniae*, *H. influenzae*
Community Acquired Bacteremic Syndromes in Young Nigerian Children (CABSYNC)	Nigeria	https://www.unmc.edu/pediatrics/research/ifain/projects/index.html	NIH and BMGF	Academic	2008–ongoing	Unselected but including GLASS pathogens

Community Acquired Pneumonia and Invasive Bacterial Diseases in Young Nigerian Children (CAPIBD)	Nigeria	http://www.ifain.org/projects/capbid/	NIH and BMGF	Academic	2012–18	Unselected but including GLASS pathogens
Burden for Antimicrobial resistance in Neonates in Developing Societies (BARNARDS)	Nigeria, South Africa, Rwanda, Ethiopia	https://www.ineosoxford.ox.ac.uk/research/barnards	BMGF	Academic	2015–18	GLASS pathogens
Group for Enteric, Respiratory, and Meningeal Surveillance in South Africa (GERMS-SA)	South Africa	https://www.nicd.ac.za/wp-content/uploads/2019/11/GERMS-SA-AR-2018-Final.pdf	South Africa Government	Government	2003–ongoing	GLASS pathogens

of AMR will be largely unreliable and may not inform meaningful action.

There is methodological homogeneity in the aspect of testing standard, which is consistent across all systems, though major differences exist in the uniformity of parameters being collected and reported. When parameters that are reported in one system are not reported in another, it causes controversy in surveillance data reliance and utilization. In addition, with the increasing demand of surveillance data for public reporting, homogeneity of surveillance methods will help to highlight best practices, enable benchmarking and enhance regional aggregation of data.[30] Interestingly, all identified surveillance systems perform AST as standard, and in addition South Africa also performs WGS. AST is a widely used method to guide clinical decision-making for highly resistant pathogens; it is also effective and efficient for tracking resistance of specific pathogens to a wide range of antimicrobial agents and it is in line with WHO testing standards. Despite the popularity of this method of testing, there are questions around its sensitivity profile and timeliness. Studies have reported that in addition to AST, WGS is another valuable method that systems could consider for AMR surveillance.[31–33] WGS offers a paradigm shift in laboratory testing, which is different from the traditional techniques that involve exposing pathogens to different antibiotic concentrations to determine susceptibility, plus an added benefit of results availability within the day.[34] Though this method is unlikely to replace the traditional AST method in the nearest future, with the ever evolving dynamics of resistant pathogens, a rapid testing technique that delivers quick molecular results will effectively support AMR surveillance.

Another important finding from this review is the absence of EQA in the majority of the surveillance sites/laboratories and a poor technical level of standardization of data management. EQA provides valuable data information and helps ensure that laboratory results are reliable.[35] Quality assurance is the hallmark of a standard surveillance system and its absence in laboratories impacts on the integrity and assurance of data.[36] It is important for laboratories to subscribe to a sustainable EQA scheme operating to internationally recognized standards. The WHO has outlined some sets of EQA with potentially more adoptable indicators suited for laboratories in poor settings yet the uptake is still poor. The poor uptake of this quality assurance tool in the region negates the ability of results to be used as reference for clinical information. Another constraint is the mode of data entry, which is not standardized across the WHO African region and the non-use of WHONET software for data recording. WHONET is Windows-based database software designed for the management of microbiology data. It provides an automated process for categorization, referencing, retrieval and analysis of data and supports seamless sharing of surveillance reports. Surprisingly, despite the usefulness of WHONET in surveillance data handling, systems generally record surveillance data on computers and on paper, which limits data sharing and is unsafe for data preservation. These data management methods impact on the timeliness attribute of the surveillance system, which is assessed by the flow of data across the system from collection, transmission, analysis and reporting. Lack of standardization of data entry and management, poor quality assessment and accreditation of data sources, and absence of checks on data reporting, analysis and sharing give rise to

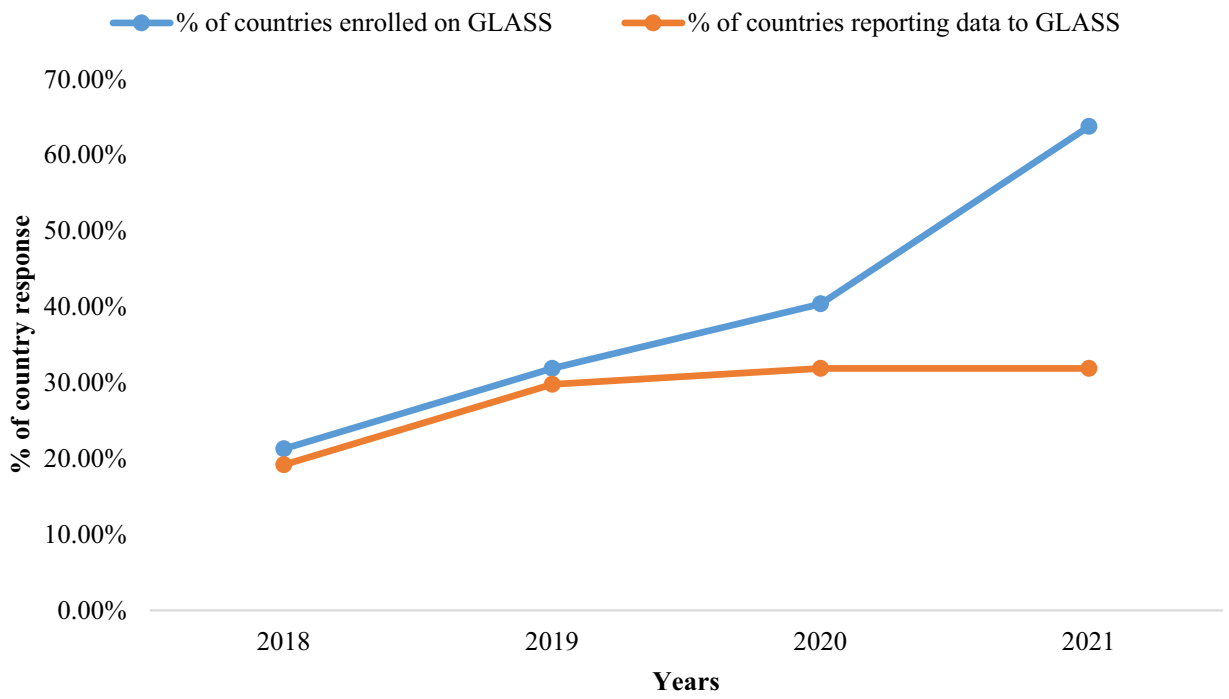

Figure 3. Percentage of countries enrolled to GLASS and countries reporting surveillance data to GLASS for the period reviewed. The percentage of the respective parameters (enrolled and reporting) were calculated for each year using 47 as the denominator. This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

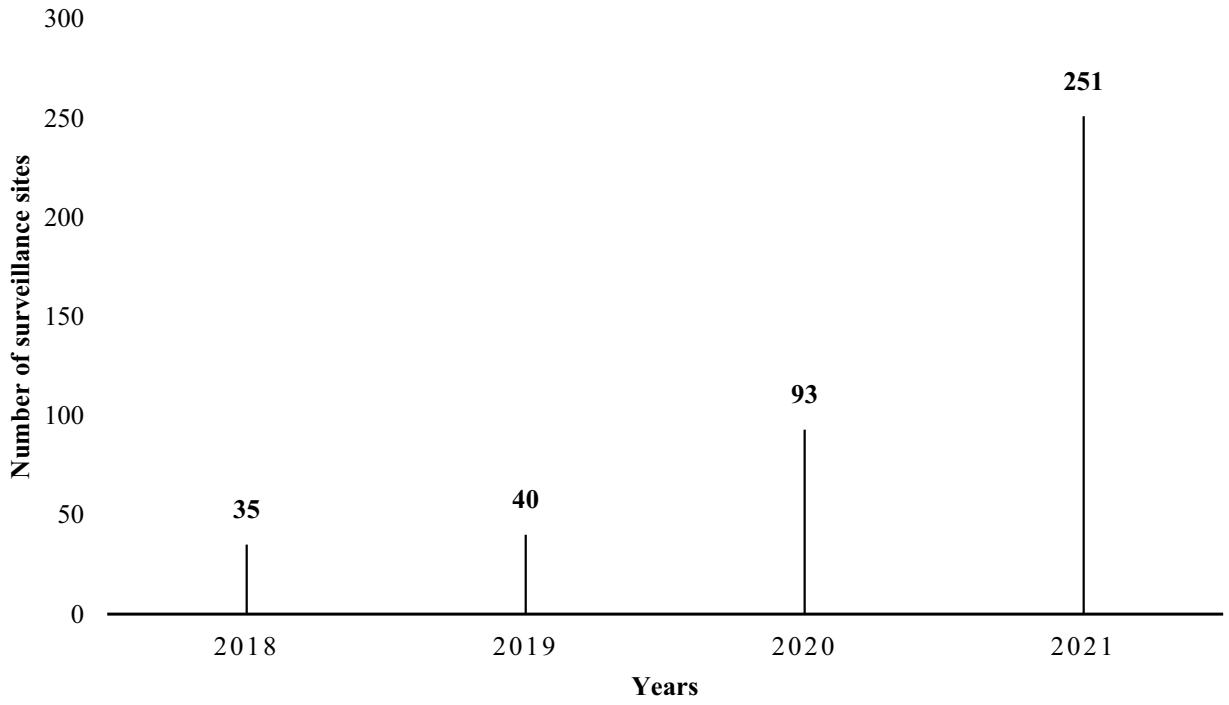

Figure 4. Trends in the increase of the number of surveillance sites reporting data to GLASS for the period reviewed.

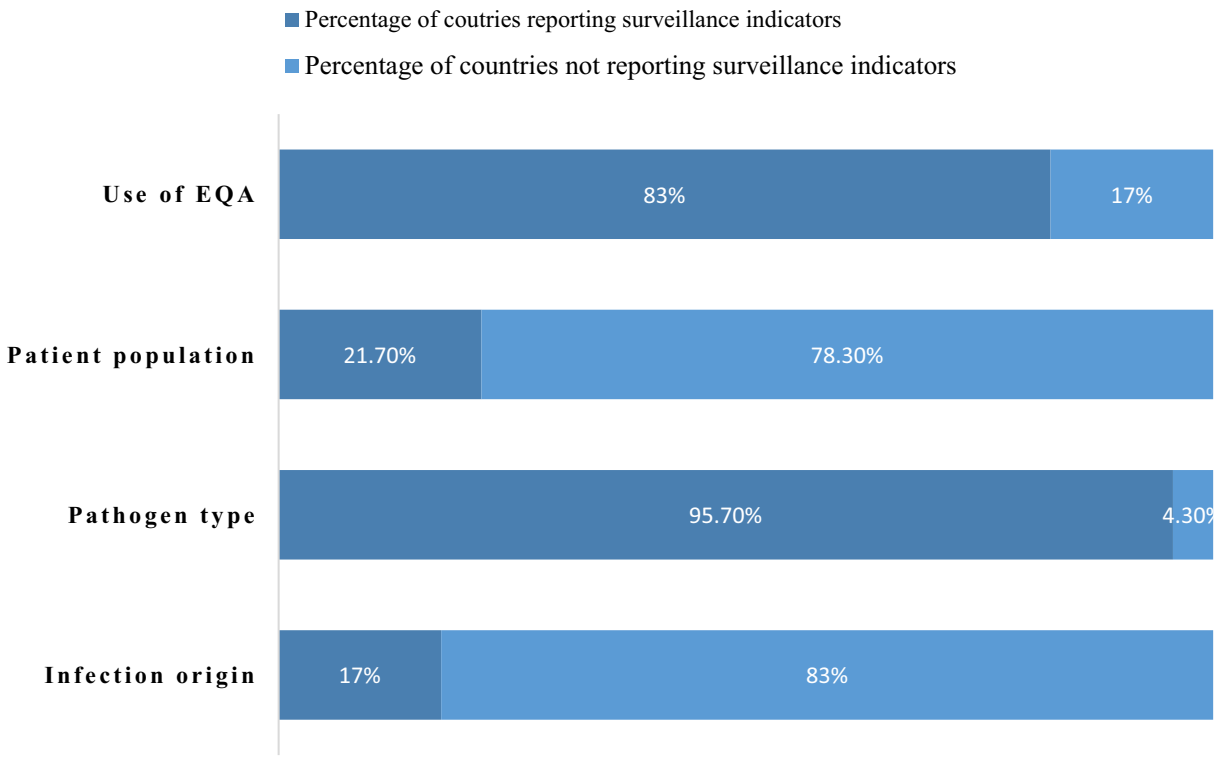

Figure 5. Percentage of systems reporting important surveillance indicators. This figure appears in colour in the online version of *JAC* and in black and white in the print version of *JAC*.

duplication and sampling bias, which further limit representativeness of data.[37] While some systems have widespread population coverage, others report data from a subset of local laboratories and healthcare settings, which focuses on one locality thereby further limiting data representativeness at a national level.

The use of a laboratory-based approach for AMR surveillance is consistent across the region. Though laboratory-based surveillance is widely in use and serves as an efficient strategy for capturing trends in resistance over time, some studies argue that this approach limits understanding of the extent to which laboratory results can inform public health policy on AMR.[38,39] These studies recommend an integrated model, which is more informative, lower cost and combines clinical, laboratory and demographic surveillance at sentinel sites.[38–40] To achieve the most effective surveillance approach for the region, a robust comparative analysis is required to inform best practices that will be cost saving and beneficial to LMICs.

Another notable finding from this review is the evidence of GLASS participation. A review of three reports[13,41,42] shows that the number of countries that have completed GLASS enrolment from the region increased significantly, as well as the number of countries reporting surveillance data to GLASS. This increasing trend shows significant progress from the level reported in an earlier study and demonstrates improved awareness and acceptance of the importance of sharing valid data in the containment of AMR.[11,43] Although the increased enrolment and reporting to GLASS is encouraging, it is important to mention that enrolment by itself does not account for the presence of surveillance, and data reporting does not guarantee submission of high-quality or representative data. To inform public health opinion for scientific and monitoring purposes, surveillance data need to be collected systematically and analysed for trends, prevalence and other relevant information. Currently the quality of data reported differs substantially, which impacts the usefulness of such data. Whilst GLASS serves as a unified network for systematic collection of surveillance data, it also facilitates long-term and sustainable investments by countries and supports the provision of epidemiological and clinical data. It is useful for more countries to join GLASS and contribute to the robust data needed for global AMR containment in a sustainable and pragmatic way. The region is still trailing behind at this given that the number of countries reporting surveillance data to GLASS is only a fraction of the number of countries in the region.

Conclusions

Surveillance remains a cornerstone for tackling AMR, and surveillance data serve as a reference point for estimating morbidity and mortality figures. There is general agreement that data collection processes for AMR need strengthening, particularly in the context of developing countries.[44] Data collected from the region differ substantially and are marred by unreported/underreported parameters, which impacts negatively on data integrity. There is a global call for sufficient data to enable full understanding of the magnitude of AMR and to direct policy action. To successfully fill this data gap, data must be reliable, truly representative of the population and collected in a systematic manner. This will not only ensure that development of policies and strategies is

informed by the country situation in an effective way but will also enhance global AMR containment efforts. Although findings from this review show that surveillance has been increasingly implemented in the region, a number of methodological issues exist that can affect validity, reliability and usefulness of these surveillance findings. Such data will not only misinform selection of the appropriate group for surveillance, they will also misguide the choice of region or setting and the priority patient population for randomized trials and other therapeutic interventions. There is also a lack of an evaluation framework that can systematically assess performance of surveillance systems for AMR. This highlights the need for the development of specific tools that can be used specifically to evaluate surveillance systems for AMR, particularly in developing countries.

Study limitation

Some information used for this review was retrieved from country self-assessment reports, which come with intrinsic limitations such as exaggerated responses, underreporting of weaknesses or overestimating of strengths. Although the authenticity of such reports was verified, they could be subject to self-reporting bias. Another limitation is that of the 35 NAPs detected, only 17 English and 2 non-English NAPs were publicly available and only 23 of these NAPs have translated into surveillance activities. These constraints have limited the robustness of data reported in this review.

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Transparency declarations

All authors have no conflicts of interest.

Author contributions

O.J.O., S.U.I. and E.C.A. contributed to the conception and design of the study. The literature search was performed by O.J.O. and U.L.I. Article screening and data extraction was done by O.J.O. and I.U. while synthesis of findings and article write-up was performed by O.J.O. Final review and critiquing was carried out by E.C.A. and S.U.I. All authors read and approved the final manuscript.

Supplementary data

Tables S1–S3 are available as Supplementary data at *JAC* Online.

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