Digital Monitoring of Antibiotic Resistance (ABR) in Low- and Middle-Income Countries: A Narrative Literature Review

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Abstract

The objective of this narrative review is to provide an overview of the knowledge and gaps in the existing research on digital Antibiotic resistance (ABR) monitoring in Low- and middle-income countries (LMICs). ABR presents a complex threat to global health. One of the key global priorities is to address this challenge through effective monitoring. An analysis of the literature revealed the missing role of IS (Information systems) research in digital ABR monitoring. A thematic analysis of the identified literature on digital interventions for ABR revealed several gaps. This research contributes by providing potential research directions and identifying the role of IS research in ABR.

Keywords

ABR, AMR, surveillance, monitoring, LMICs, digital platforms

Abbreviations

ABR – Antibiotic Resistance; AMR – Antimicrobial Resistance; NAP – National Action Plan; GAP – Global Action Plan; WHO - World Health Organization; IS – Information System; LMICs – Low- and middle-income countries; TrACSS - Tripartite Antimicrobial Resistance Country Self-Assessment Survey; SDGs - Sustainable Development Goals

1 INTRODUCTION

Antibiotic resistance (ABR) presents a widespread, complex threat to global health and universal health coverage [1]. ABR occurs when microorganisms like bacteria, viruses, parasites, fungi, and other pathogens develop resistance to the drugs used to fight them. The term ABR is used especially for antibiotic resistance in bacteria and is a subset of Antimicrobial Resistance (AMR). Globally, an estimated 700 000 deaths are attributed to ABR annually, with a projected economic impact of US$100 trillion by 2050 [2]. ABR threatens the effectiveness of treatment of infectious diseases and consequently the sustainability of health systems globally [3]. The adverse consequences of ABR extend to the environment, food production, poverty, health security, and attainment of the Sustainable Development Goals (SDGs) underscoring the need for both global and local research and practical action to address this huge challenge[4].

The World Health Organization (WHO) report on global surveillance of ABR in 2014 highlighted the immediate need for global action to identify actionable information on pathogens and monitor trends of resistance [5,6]. The WHO released a global action plan (GAP) in 2015 and recommended for countries to develop national action plans (NAPs), with a focus on strengthening the knowledge and evidence base through digital-based surveillance and monitoring to strengthen policy and practice[7]. At the policy level, surveillance and monitoring can help in making better estimates of geographical trends and patterns of resistance which can guide decisions related to resource allocation and the building of regulatory frameworks. At the clinical or practice level, effective monitoring can help develop an evidence base for targeted treatment, build infection control practices, and guidelines for antibiotic prescription practices.

Despite the development of these global and national frameworks, LMICs lag far behind in their effective implementation. While 163 countries have developed NAPs to combat ABR, very few have materialized them in practice [8,9] and, ABR continues to expand mortality and morbidity rates [10]. LMICs are the worst hit with the least resources, including for diagnostic, poor regulation, ad hoc prescription practices, and limited data on the epidemiology of resistance [6,7,11,12].

Surveillance data at local, national, and international levels is needed to guide patients' treatment, inform health policies, trigger responses to health emergencies, and provide early warnings for outbreaks [1]. Current data on ABR surveillance in LMICs are fragmented and lack representativeness [13]. The major sources of ABR data in LMICs are mainly tertiary hospitals, some pharmaceutical companies, private labs, and limited academic literature on the patterns of use of antibiotics [14,15]. Identifying existing research gaps is of crucial importance and a central focus of this paper.

This study aims to provide a narrative literature review and analysis of the existing research related to the applications of digital solutions for monitoring ABR from an LMIC perspective. This paper discusses the existing literature, identifies key gaps, and makes some suggestions for strengthening these identified gaps. While ABR refers to the health of humans, animals, and the environment, referred to as One Health, this paper focuses only on human health in the context of LMICs. We particularly examine what has been the contribution of Information Systems (IS) research to this domain and how can this be enhanced in the future.

2 METHODS

In this study, a narrative literature review was done for data collection to gather and summarise existing research literature on this topic, and to identify dominant themes addressed and directions for future research.

2.1 Search strategy

The existing research on ABR was searched in the AIS elibrary which is a repository of all the major IS research, including the basket of seven articles. The initial focus of the search was to identify the information systems research related to ABR. However, the search yielded no results, and the search was then extended to Scopus to identify literature on digital monitoring of ABR as it is a repository of major life sciences, social sciences, and health sciences research. The search was broadened to use generic keywords to identify papers even outside the IS domain.

The keywords for database search were identified based on the research focus. An initial search was performed in the Scopus database using the keywords “Antimicrobial resistance”, “Antibiotic resistance”, “Surveillance” and “Monitoring”. surveillance” to obtain a better understanding of the breadth of studies and their focus. Based on the result of the initial search, the scope of the search was defined to include a focus on only literature related to digital ABR monitoring in LMICs in the human domain.

Search terms used included “antimicrobial resistance”, “antibiotic resistance”, “digital surveillance”, “digital platform”, “information system”, “digital monitoring”, LMICs, low- and middle-income countries, and developing countries. The title, abstract, and keywords were searched in May 2022, and no time filter was applied to the search.

2.2 Selection of studies and data retrieval

The metadata query with the selected keywords was used and the search was limited to scientific papers in the English language, papers published from 2011 until 2022 (as of this article’s submission date), and full author information available. These articles were manually screened to identify relevant articles while applying the following exclusion criteria:

- Duplicate articles.
- Articles (the reading of the abstract, introduction, discussion, and conclusion) that were irrelevant to the focus of the study.

The inclusion criteria applied:

- All articles published from 2011 until 2022 (at the time of submission).
- Cited and uncited articles.
- Abstracts (abstract, introduction, discussion, and conclusion) and titles relevant to the theme of study.

2.3 Data analysis

A thematic analysis was then conducted on the identified articles. The technique of thematic analysis was chosen because it is a suitable interpretive method that helps to uncover key concepts and patterns in a data set [16]. It is a dynamic way to understand and generate explanations from data or to explore an a priori theoretical understanding of a phenomenon under study [17,18].

3 RESULTS

The initial database search in the AIS eLibrary yielded no studies on antimicrobial/antibiotic resistance in the IS domain. An ABR monitoring system is the lifeline of a surveillance and monitoring program to tackle the grand societal problem at all levels including global, national, regional, and facility-specific initiatives. Given the grand nature of the problem, a multidisciplinary approach and collaboration to act at the practice and policy levels are needed but the problem is largely invisible in IS research which could play a guiding role in the realization of the potential of the digital.

The database search in Scopus yielded 870 records which were filtered to 77 after the use of relevant keywords and after removing duplicate papers. The titles, keywords, abstracts, discussion, and conclusions of these papers were further screened, and 37 papers were removed which were found irrelevant. Further, 40 records were considered for detailed assessment of full text and excluded 28 papers not meeting one or several of the inclusion criteria. A total of 12 relevant studies were included in the detailed review. The PRISMA flow chart shows the number of records/studies at each stage (Figure 1).

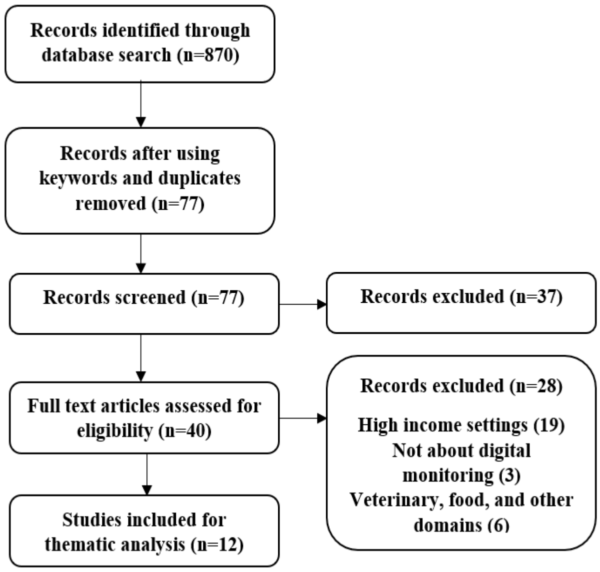

Figure 1: PRISMA flow diagram

3.1 Characteristics of the included studies

Articles from the following LMICs were identified: India, Cambodia, Uganda, Laos, Vietnam, Thailand, Iran, Nepal, India, Bangladesh, Indonesia, Maldives, and East Timor (see map below). The digital technologies discussed included the widely used WHONET[1] for data capture, Global Antimicrobial Resistance and Use Surveillance System (GLASS[2]), DHIS2[3] (District Health Information System), and other proprietary in-house developed applications. The red lines in figure 2 demonstrate the list of countries from the research articles included in this review.

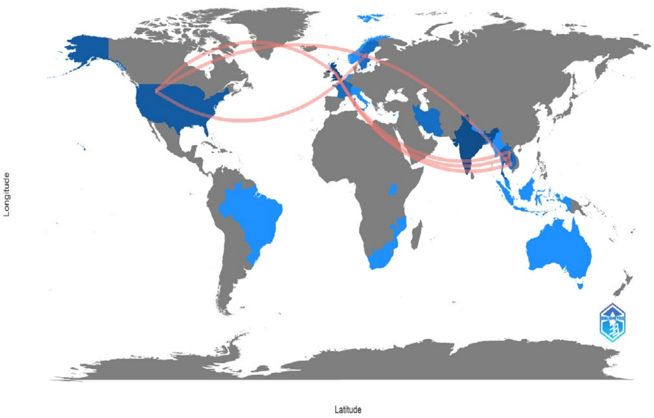

Figure 2: List of countries represented in the review articles

A summary of the key characteristics of the identified papers is summarized in the table below and is then briefly discussed.

Description	**Results**
Timespan	2011:2022
Sources (Journals, Books, etc)	11
Documents	12
Average years from publication	3.17
Article types	
Journal papers	9
Conference paper	1
Review	2
Sources	
Wellcome Open Research	2
Antimicrobial Resistance and Infection Control	1
BMJ (Online)	1
BMJ Global Health	1
Drug Resistance Updates	1
Frontiers In Public Health	1
IFIP Advances in Information and Communication Technology	1
International Journal of Medical Informatics	1
JMIR Public Health and Surveillance	1
Journal Of Global Antimicrobial Resistance	1
Journal Of Medical Internet Research	1

Table 1: Key characteristics of the identified articles

The articles specifically discussing the digital monitoring of ABR were considered for the study. 12 articles from the period 2011 to 2022 were selected. The selected list included 9 research papers published in journals, 1 conference paper, and 2 review articles. These selected articles were from 11 different outlets. The articles appeared in global public health journals like BMJ global health, BMJ online, Frontiers in public health, and reviews from Wellcome open research.

However, the presence of the importance of the digital in ABR is missing from journals setting the global health agenda. There is an absence of articles in disciplines other than those clinically relevant. Most articles are from global public health journals discussing the importance of ABR monitoring from a global and national perspective. Only one conference paper from the list discussed the relevance of digital systems relevant for multiple contexts at global, national, regional, and facility levels for ABR.

The details of these papers including the main author, country of study, year of study, digital technology used, implementation context and level, and the main findings are presented in Annexure 1. The themes identified from a deeper analysis of the research articles are presented in the next section.

3.2 Analysis: Identifying themes

A content analysis based on a detailed reading of the identified papers was done. Related themes were classified and coded in groups. These codes were reassessed based on further reading and final relevant themes were identified: i) Marginal role of context; ii) Inadequate consideration of scale; iii) Relevance of open-source platforms not considered

3.1.1 Marginal role of context

Context can be defined as "situational opportunities and constraints that affect the occurrence and meaning of organizational behavior as well as functional relationships between variables"[19]. This specifies the role and importance of the development of policies, frameworks, guidelines, and technology based on the *context* where they are implemented. Context-specific development is relevant in the case of ABR since the nature of the problem varies in different contexts and especially in the case of LMICs which are burdened by multiple structural and societal issues in addition to the burden of infectious diseases.

[1] WHONET is a desktop windows application for the management and analysis of microbiology laboratory data with a particular focus on antimicrobial resistance surveillance developed and supported by the WHO Collaborating Centre for Surveillance of Antimicrobial Resistance.

[2] Global Antimicrobial Resistance and Use Surveillance System (GLASS) is a global collaborative effort to standardize WHONET is used at the facility/lab level to capture data which is then aggregated and imported to GLASS in a specific format annually.

[3] DHIS2 is an open source, web-based platform most commonly used as a health management information system (HMIS) and for case-based data capture and analysis

Six out of twelve studies included the analysis discussing the framework for ABR monitoring at global levels using WHONET and GLASS. All these initiatives rely on good quality data from the micro or the hospital levels to enable monitoring at national and global levels [20]. One of the studies indicates that among the 136 countries reporting to the Global Database for the Tripartite Antimicrobial Resistance Country Self-Assessment Survey (TrACSS) in 2019–2020, only 32 (24%) countries include integrated multisectoral ABR surveillance and monitoring in their NAPs [20]. However, the frameworks developed for use of these applications in LMICs have limited discussions about the context-specific challenges [23,24].

Studies are done at the hospital level, or the department level to identify the need for a patient-based application that could guide them at the practice level and provide information about the local and geographical resistance profiles. Turner et. al. [25] identified the need for a clinically oriented digital tool that could guide at the hospital level as GLASS lacks clinical metadata on antibiotics prescription and use at the local level and the duration of hospitalization. Similarly, Vong et. al. [26] in their study on the use of digital applications for monitoring ABR in seven Asian countries including hospitals in Thailand, Nepal, India, Bangladesh, Indonesia, Maldives, and East Timor identified the need for patient-specific information to act at the local level.

Guidelines for technology and monitoring developed at global and sometimes national levels for countries like India with diverse health profiles in different areas that lack contextual information often fail at the implementation stage. One such example is the poor implementation of NAPs in the countries where specific challenges of implementation are not considered in the plans developed at global and national levels. For example, the guideline to develop a monitoring system at the national level without considering the local challenges of capacity and resources like poor internet, lack of manpower, etc at the contextual level.

3.1.2 Inadequate consideration of scale

Designing for scale means building relevance both for the local facility level and the multiplicity of contexts, within the framework. Such a focus continues to enhance the local value of the processes while also enabling them to be expanded easily to new contexts [27]. ABR represents a unique challenge of scale and scope both geographically and functionally, as it is a global problem without geographical constraints. Functionally, ABR data is not only needed from the microbiology lab at a hospital but also in other departments of the hospital like the antibiotics prescription patterns from the clinical prescription data, etc. to strengthen hospital-wide activities of managing hospital-acquired infections and infection prevention and control activities.

Vong et al. [26] identified challenges with the implementation and use of WHONET in the LMIC context and discussed constraints like configuration of WHONET and BacLink, system interoperability, lack of data standards, and lack of a well-trained local and national IT workforce. Another study in an LMIC context in the Republic of Laos, Vietnam, Myanmar, Thailand, and Vietnam used a locally developed offline application to generate reports for use at the hospital level[26]. This allowed the hospital under study to generate standardized reports that allowed easy comparison of resistance among facilities. However, challenges were presented with analyzing data and generating a report as lengthy and time-consuming processes a sit required intensive manual work and trained personnel which is an existing challenge with LMICs. One of the selected studies to study the strengthening of surveillance and monitoring in India discusses the features of an in-house developed application [28] that captures and analyses the data collected from 25 tertiary hospitals from the human domain in the country. The limited data submitted to GLASS [13] by India presents the grave challenge of surveillance and monitoring as the data from a total of 71 facilities is sent to GLASS annually from a country with a population of 1.37 billion and more than 200,000 public health facilities across the country [28]. However, most digital applications in the documented articles are being implemented and used at tertiary facilities with limited discussion to scale to public and community facilities. Another study evaluated the use of WHONET and GLASS in a research project to monitor ABR from 2015 to 2020 at a few hospitals in Uganda [29]. The data collected and analyzed during the project duration is planned to be used to guide ABR policies in the country. However, the plan to scale and routinize the use of technology was not discussed in the study.

Among the articles included in the review, 5 studies [24–26,28,30]on monitoring and surveillance of ABR at regional or hospital levels identified the need for systems to collect hospital-specific information but because of the lack of standards in data collection and analysis, the information sharing becomes impossible4. The systems developed at the local level thus have limited considerations to scale to different contexts, both geographically and functionally. There are limited studies discussing the challenge of scale in ABR monitoring in LMICs. Only one study discussed the scaling of digital technology for monitoring ABR at multiple levels [31].

3.1.3 Relevance of open-source platforms not considered

Open-source platforms are not only cost-effective by allowing free usage of the platform without having to pay the licensing and maintenance fee, but they are also flexible and scalable. They allow the use of global standards while providing the flexibility to configure the local and user-specific requirements. The use of free and open-source software platforms for the collection, management, analysis, and use of ABR monitoring data is imperative for LMICs struggling with existing challenges of capacity and resources.

One of the main barriers to adopting digital technologies in LMICs is the cost of its purchase and maintenance, which highlights the open-source approach as a good solution for resource-constrained areas [32]. In-house development using proprietary platforms limits the scaling of the application to other contexts and is expensive to maintain. The monitoring platforms to capture and analyze data for ABR developed using proprietary sources in the reviewed articles have presented challenges like lack of system interoperability and lack of data standards. This limits the scope of the applications and limits the standardization of data analysis [26,28]. Vong et.al. [26] in their study based on high-level discussions between SEARO countries about challenges in ABR monitoring and surveillance, collate the requirements for ABR monitoring in the participating countries. They state the need for an open-source application that is easier to maintain and enables standardized data collection, analysis, and reporting at hospital levels, and allows sharing of data in a standardized format to a central level to guide policy and necessary action. Sahay et. al. [31] discuss the geographic and functional scaling of an open-source platform to capture, analyze and use data to guide both practice and policies at multiple levels.

The studies included in the review (Appendix 1) discuss the challenges with digital platforms developed locally. Four articles included developed the technology locally for facility-specific requirements, but experienced challenges as stated above. This represents an urgent demand for both advanced knowledge and technology which is open-source, reliable, and flexible for ABR monitoring systems, especially in low-resource settings.

4 DISCUSSION

The narrative review provides an overview of the current knowledge and existing gaps in digital ABR monitoring and surveillance in LMICs. The studies presented discussed the development of frameworks and plans for ABR and the use of digital applications at global and national, regional, and facility levels. However, at the facility level, several challenges are encountered to bring the guidelines to practice during the implementation of digital technologies with limited scalability to other contexts. Based on the results, directions for future research on digital monitoring of ABR in LMICs are now discussed that could potentially guide in solving the complex and interconnected pieces of the puzzle.

4.1 Future Research Directions

Building upon our thematic analysis, we provide some suggestions on how future research in this domain of ABR monitoring in LMICs can be further strengthened.

4.1.1 Interdisciplinary research efforts

An interdisciplinary approach entails interaction, collaboration, and cooperation among scientific, academic, and non-academic disciplines, researchers, and stakeholders, to integrate scientific, technical, and non-technical knowledge as bases for policymaking at the higher level and context-specific implementation at the practice level [33]. The need for an interdisciplinary approach to tackle ABR is well documented because of the interconnected domains like human, veterinary, food, environment, etc., and the involvement of multiple stakeholders[34].

A lack of focus on ABR in the existing IS literature indicates a significant scientific and practical vacuum. This vacuum is particularly striking when we consider the magnitude of the ABR domain. In the context of increasing calls for building one-health approaches to ABR research [35], where digital monitoring is pivotal, IS research needs to become more relevant in guiding the realization of the potential of the digital. Building digital monitoring systems in LMIC settings is not limited to one hospital or nation, it is a global interconnected, and complex issue, making it a wicked problem that demands interdisciplinary and collaborative approaches. However, 10 out of 12 of the studies identified in the literature are from public health journals written either by medical or clinical and public health professionals.

Supplementation of ABR research with a social systems approach to IS research can help in the development of monitoring systems guided by the problem context with the expertise from both clinical/medical and IS researchers and help to facilitate contribution towards antimicrobial stewardship (AMS) interventions. A social systems approach to IS discusses the problems of design and implementation of digital technology as an interplay of human, organizational, social, and technical factors[36]. It is particularly relevant for ABR and the LMICs perspective as the context-specific design and implementation of monitoring systems must involve an understanding of these factors and in which the digital technology is to be implemented and used for its adoption by the end users[34,37]. It can potentially provide insights into the specific challenges like a better understanding of the structural issues aggravating the problem to make decisions at policy and practice levels. For example: At the facility level, an ABR monitoring system could potentially make the issues visible like prescription practices of antibiotics and data quality issues at the practice level and the use of this data to make an antibiotic policy at the policy level.

4.1.2 Advocating systems thinking approaches

Systems thinking is an approach widely used to address and solve complex problems, including those relating to information systems [38]. It is the consideration of systems in their totality, as their constituent parts and their interactions, as well as their interaction with the wider environment [37]. ABR is considered to be one of the most complex problems and a global threat that cannot be solved by focusing on individual processes [39] and will benefit through the application of multiple research lenses.

It requires a focus on understanding the problems as a whole from multiple perspectives like medical/clinical, IS, public health, etc to identify different underlying components, and challenges, and predict behaviors. This could be done by a system thinking approach to examine and analyze the underlying problems and plan interventions accordingly. The participation of stakeholders and experts from different domains while using a systems approach can potentially increase stakeholder engagement and ownership of the new knowledge generated through the process by allowing ideas to the incorporation from different perspectives and encouraging a participatory approach to solving a problem [40].

The systems thinking approach has been applied to a variety of societal issues of global impact like environmental challenges and policy, climate change, and disease eradication programs [41,42]. However, the problem of ABR has remained untouched by the systems thinking approach. Considering the complexity and seriousness of the issue, a system thinking approach must be used to evaluate the problem, existing interventions, and their impacts and to plan the future interventions accordingly by considering the problem as a whole consisting of clinical, social, ecological, and cultural, economic constituents. For example, the problem of the irresponsible use of antibiotics is the major reason for the occurrence of ABR. Antibiotics use is a complex issue resulting from a chain of events in an ecosystem with multiple subsystems and involves the actions of multiple stakeholders. E.g.: Prescription practices of physicians, dispensing practices of pharmacists, patterns of use of antibiotics by patients, etc. The practices of these stakeholders are affected by the underlying social and cultural factors and to address the issue an evidence base is needed to act. Social sciences research combined with an IS approach could potentially guide at the practice level by providing an evidence base for the physicians to prescribe antibiotics responsibly and guide the development of infection control and antibiotics use policies etc.

4.1.3 Research influencing practice

The research-practice gap occurs when knowledge acquired through research in an academic environment is not integrated with real-world clinical practice [43]. As standards of care continue to evolve, there can often seem to be a disconnect between what is considered best practice and actual practice. Several contributing factors result in the research and practice gap. For example, communication gap between researchers and practitioners, service delivery issues including lack of awareness and knowledge, lack of political and economic support, etc [44]. Several other factors have been documented like the interventions being narrowly or too broadly focused, complex, difficult, and costly, or may not engage or meet the perceived needs of the community at the practice level. ABR interventions are a classic example of the research-practice gap as there are several policies and frameworks defined at the global and national levels, GAPs and NAPs but these are poorly implemented at the practice levels [22]. Local practitioners identify challenges with the implementation of global platforms like WHONET and face challenges in configuring and interoperability etc [26] and GLASS does not provide patient-based information at the hospital level and lacks clinical metadata on antimicrobial use and duration of hospitalization [25]. The challenges in implementation are also cultural, lack of experience, and require context-specific solutions to meet global standards and to meet the needs at the practice level. IS research integrated with clinical research on ABR could help in the development of a context-specific evidence-based to taking local actions at the practice level that could potentially be scaled to other contexts.

5 CONCLUDING REMARKS

Arguably, this paper is a first step in arguing the potential role that IS research can have in strengthening ABR research and practice, and some suggestions on future areas of focus. While acknowledging this is indeed only touching the tip of the iceberg, it is required and urgent. A key role for IS research is in guiding the design, development, and implementation of context specific ABR digital interventions supplemented with expertise from other disciplines. This study proposes three future research directions which can help guide efforts and interventions for implementing digital ABR monitoring efforts in varying LMIC contexts, which would need to be applied in practice and further evolved with experiences.

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Appendix 1: Details of the articles included in the review

First author, year (country)	Digital technology used	Setting and level of implementation	Main results
Kaur J, 2022 (India)	i-AMRSS (Web-based digital AMR surveillance system)	Used for data collection from 30 tertiary hospitals	Locally developed application for monitoring. The study discussed features of the tool and the possible analysis and the possibility to extend to veterinary and other domains possible
Nabadda S, 2021 (Uganda)	WHONET/GLASS	At specific surveillance sites in the country from 2015 to 2020	Data collected during the project duration to be used to guide policies. However, no plan for country-wide surveillance is described.
Iskandar K, 2021 (Review of data sources for LMICs)	Review of available data sources for LMICs Requirement assessment for LMICs. Experience from implementation in Georgia		The barriers and limitations of conducting effective antimicrobial resistance surveillance in LMICs and highlight multiple incremental approaches that may offer opportunities to strengthen population-based surveillance if tailored to the context of each country.
Sahay S, 2020 (India)	DHIS2(District health information system)	Facility/hospital level	Design and implementation of an open-source application for AMR monitoring at a facility with the possibility to scale both functionally and geographically.
Turner P, 2020 (Laos, Vietnam & Cambodia)	WHONET/GLASS	Plan to pilot in one facility each in the three countries	Digital surveillance to build on GLASS as it does not provide patient-based information at the hospital level and lacks clinical metadata on antimicrobial use and duration of hospitalization
Rezaei-hachesu P, 2018 (Iran)	Requirements analysis for a surveillance system	Neonatal Intensive care units (NICUs) at 2 tertiary hospitals in Iran	Framework for the design of an AMR/ABR surveillance system for use in the NICUs in north-western Iranian hospitals to cover information gaps and proposes three modules for monitoring: the data registry, dashboard, and decision support
Safdari R, 2017 (Iran)	GLASS	Review of literature on existing digital surveillance systems	The study developed a framework for the design and implementation of a national ABR monitoring system building on GLASS
Seale A.C, 2017 (WHO GLASS countries)	GLASS	Review of literature on existing digital platforms	A roadmap for participation in the Global Antimicrobial Surveillance System (GLASS)
Oberin M, 2022 (Review of existing digital platforms)	Review of existing digital platforms- to identify solutions for monitoring in all domains	Review of existing digital platforms	No EIS for AMR surveillance was identified that was designed to integrate a broad range of AMR data from humans, animals, and the environment, representing a major gap in global efforts to implement One Health approaches to address AMR.
Lim C, 2020 (Thailand)	Antimicrobial resistance Surveillance System (AMASS)	One hospital in Thailand	An offline application to generate standardized AMR surveillance reports in the R programming language. The challenges presented with analyzing data and generating a report as lengthy and time-consuming processes that require trained personnel.
Vong S, 2017 (Seven Asian countries)	WHONET	Global and National	Constraints of Information technology surveillance like configuration of WHONET and BacLink, system interoperability, lack of data standards, etc
Grundmann H, 2011	WHONET/GLASS	Global	Framework for AMR/ABR surveillance at global/national/regional levels