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Antimicrobial Resistance Surveillance and Diagnostic management

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Abstract

Antimicrobial resistance (AMR) has increased globally over recent decades, due to the rise of resistance patterns, limited diagnostic capacity, and persistent gaps in surveillance systems. These challenges continue to prevent early detection efforts and reduce public health responses across diverse health settings. In this context, diagnostic management encompassing laboratory capacity, antimicrobial susceptibility testing, and adoption of rapid diagnostic tools has gained prominence as a important component for enhancing AMR monitoring and informing treatment decisions. This study evaluates the effectiveness of diagnostic management within AMR surveillance frameworks, with a focus on how diagnostic readiness, testing accuracy, diagnostic processing time, and health management practices contribute to the reliability of surveillance outcomes.

A qualitative documentary analysis approach is adopted, integrating evidence from verified global surveillance reports, national situational assessments, peer reviewed studies, and technical policy documents. Findings shows that strong diagnostic systems improve the quality, completeness, and responsiveness of AMR surveillance data, providing both theoretical contributions to AMR literature and practical insights for health system advancement. The study is also significant for guiding policy formulation, resource allocation, and the integration of advanced diagnostics tools in settings where laboratory capacity remains limited.

Keywords: Antimicrobial resistance; Diagnostics; Surveillance; Laboratory capacity; Stewardship; AMR management

1. Introduction

Antimicrobial resistance (AMR) has become one of the most critical global health threats of the 21st century, affecting every region of the world regardless of income level. The landmark Global Burden of Disease (GBD) study reported that in 2019, bacterial AMR accounted for 1.27 million deaths directly and 4.95 million deaths associated with resistance, making AMR a leading cause of mortality worldwide and been prominent than HIV/AIDS and malaria in annual impact (Murray et al., 2022). The continuous rise of resistant pathogens threatens the effectiveness of antibiotics that once formed the foundation of modern medicine, thereby affecting routine surgical procedures, cancer chemotherapy, maternal health outcomes, and the management of severe infections.

There are several factors causing the spread of AMR globally , which includes the misuse and overuse of antibiotics in humans and animals, poor infection prevention and control (IPC), inadequate sanitation systems, and insufficient access to quality assured antimicrobials (Sulis et al., 2022).The low and middle income countries are more at risk to AMR due to constrained health systems, but high income countries are not excluded, as resistant pathogens spread efficiently across borders, healthcare settings, and community environments (Iskandar et al., 2021).

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AMR surveillance forms the background of global strategies which is aimed at reducing resistance. Surveillance systems monitor the occurrence, trends, and distribution of drug resistant pathogens, enabling countries to inform treatment guidelines, detect emerging resistance, and evaluate antimicrobial healthcare interventions. The World Health Organization's Global Antimicrobial Resistance and Use Surveillance System (GLASS) continues to expand, with over 70 countries contributing AMR data by 2021 (WHO, 2021). However, persistent gaps exist as many regions still lack standardized laboratory capacity, consistent data reporting, and coordinated surveillance frameworks, making global AMR trends difficult to interpret (Iskandar et al., 2021).

To address these challenges, recent innovations in rapid diagnostic technologies including molecular assays, microfluidic devices, whole-genome sequencing, and point-of-care platforms provide a potential system that reduce diagnostic delays and improve therapeutic decision making (Kaprou et al., 2021). Despite these advances, global implementation remains uncertain due to cost, equipment shortages, regulatory gaps, and technical capacity barriers.

This study therefore aims to contribute to global understanding by examining AMR surveillance systems, diagnostic management practices, laboratory capacity, and operational challenges from a broad, international perspective. By identifying key gaps and opportunities, the research supports global efforts to improve AMR monitoring, enhance diagnostic accuracy, and inform policies for effective antimicrobial management.

1.1. Statement of the Problem

Antimicrobial resistance (AMR) continues to increase globally, yet the systems required to detect, monitor, and respond to resistant pathogens remain insufficient. The Global Burden of Disease study reported that bacterial AMR caused 1.27 million deaths in 2019, emphasizing its position as a major global health challenge (Murray et al., 2022). Despite this health burden, many countries still lack comprehensive and sustainable AMR surveillance structures capable of providing accurate and timely data. Surveillance networks frequently experience limited laboratory participation, weak quality assurance, and inconsistent data reporting, resulting in incomplete understanding of resistance patterns across regions (Iskandar et al., 2021).

Diagnostic capacity which forms the basis of reliable surveillance remains inadequate in many health systems. Culture and antimicrobial susceptibility testing (AST), which is considered the standard, are restricted by diagnostic process time, infrastructural limitations, and shortages of skilled personnel (Iskandar et al., 2021). These diagnostic challenge lead clinicians toward symptom based prescribing, contributing to inappropriate antimicrobial use and increasing resistance (Sulis et al., 2022). While rapid molecular and automated diagnostic technologies are emerging, their global adoption is limited by cost, implementation challenges, and technical requirements (Kaprou et al., 2021).

The combined limitations of weak surveillance and inadequate diagnostic management create significant challenge in AMR detection and control. Without reliable data and timely diagnostics, health systems cannot effectively guide treatment, track resistance trends, or implement targeted interventions. This gap highlights the urgent need to evaluate and strengthen AMR surveillance and diagnostic management globally.

1.2. Objectives of the Study

The broad objective of this study is to evaluate the effectiveness and challenges of antimicrobial resistance (AMR) surveillance and diagnostic management globally.

The specific objectives are to:

- Assess the structure, coverage, and performance of existing AMR surveillance systems across global health settings.
- Examine the diagnostic methods and technologies used for AMR detection, with emphasis on their accuracy, turnaround time, and operational capacity.
- Identify major challenges and systemic barriers affecting the integration, reliability, and effectiveness of AMR surveillance and diagnostic management worldwide.

1.3. Research Questions

- How effective and comprehensive are the existing antimicrobial resistance (AMR) surveillance systems across global health settings?
- What diagnostic methods and technologies are currently used for AMR detection, and how do they perform in terms of accuracy, turnaround time, and operational feasibility?

- What major challenges and systemic barriers affect the reliability, integration, and overall effectiveness of AMR surveillance and diagnostic management worldwide?

1.4. Research Hypotheses

Based on the objectives and research questions, the study proposes the following hypotheses:

- H1**:** Effective AMR surveillance systems are positively associated with improved detection and monitoring of antimicrobial resistance patterns globally.
- H2: The use of accurate and timely diagnostic methods significantly enhances the quality and reliability of AMR surveillance data.
- H3: Systemic barriers such as limited infrastructure, inadequate workforce capacity, and inconsistent data reporting significantly reduce the effectiveness of AMR surveillance and diagnostic management.

1.5. Significance of the Study

This study is significant for several reasons:

1.5.1. Theoretical Contribution

The research contributes to global AMR scholarship by integrating evidence on surveillance systems and diagnostic management within a integrated analytical framework. While existing literature often addresses surveillance and diagnostics separately, this study highlights their interdependence and provides a broader understanding of how diagnostic capacity influences surveillance quality. This adds conceptual precision to current debates and supports future comparative research across different health systems.

1.5.2. Practical Contribution

By identifying the strengths, weaknesses, and operational challenges of current AMR surveillance and diagnostic practices, the study provides valuable insights for policymakers, public health institutions, and laboratory networks. The findings can guide improvements in laboratory infrastructure, quality assurance programs, workforce training, and the adoption of rapid diagnostic technologies. Such improvements are essential for enhancing early detection of resistance, informing treatment guidelines, and strengthening antimicrobial stewardship efforts.

1.5.3. Policy Relevance

Given the growing international emphasis on AMR preparedness, the study offers evidence that can support national and global policy formulation. International bodies and national public health agencies can use the findings to refine surveillance frameworks, expand global reporting platforms, and prioritize investments in diagnostic innovations.

1.5.4. Global Health Impact

Advance AMR surveillance and diagnostic management has direct implications for improving patient outcomes, reducing inappropriate antimicrobial use, and preventing the spread of resistant pathogens. By providing actionable recommendations, this study contributes to global efforts aimed at safeguarding the effectiveness of antimicrobial agents and preventing a post-antibiotic era.

1.6. Scope of the Study

This study focuses on examining antimicrobial resistance (AMR) surveillance and diagnostic management from a global perspective. The scope covers the major components of AMR surveillance systems, including data collection processes, laboratory participation, reporting mechanisms, and the integration of surveillance findings into public health and clinical decision-making. It also encompasses diagnostic methods used for AMR detection ranging from conventional culture based techniques to emerging rapid and molecular technologies and evaluates their accuracy, diagnostic processing time, and operational requirements across different health system.

The study reviews research evidence, global reports, and published literature from various regions to understand how surveillance and diagnostic capacities differ between high-income, middle income, and low income settings. While the analysis considers global variations, emphasis is placed on identifying common gaps, systemic challenges, and factors that influence the reliability and effectiveness of AMR surveillance and diagnostic management worldwide.

The study does not focus on specific pathogens, countries, or individual laboratory systems; rather, it synthesizes insights that apply broadly across global health settings. It also does not involve primary laboratory data collection or evaluation of specific diagnostic platforms, but instead relies on existing empirical studies, technical reports, and global assessments published within the time frame relevant to AMR monitoring. The findings are intended to inform broad policy, research, and implementation strategies rather than provide pathogen specific or country specific recommendations.

1.7. Definition of Terms

- **Antimicrobial Resistance (AMR)**: The ability of microorganisms such as bacteria, viruses, fungi, and parasites to withstand the effects of antimicrobial agents that were previously effective against them, resulting in reduced treatment efficacy and increased risk of spread, morbidity, and mortality.
- **AMR Surveillance**: A systematic process of collecting, analyzing, interpreting, and reporting data on antimicrobial resistance patterns to support clinical decision-making, guide public health interventions, and monitor emerging resistance trends over time.
- **Diagnostic Management**: The coordinated use of laboratory procedures, technologies, and workflow to accurately identify pathogens, determine antimicrobial susceptibility, and provide timely results that inform treatment decisions and stewardship practices.
- **Antimicrobial Susceptibility Testing (AST)**: Laboratory procedures used to determine the susceptibility of microorganisms to antimicrobial agents, including methods such as disk diffusion, broth micro dilution, and automated systems.
- **Rapid Diagnostic Tests (RDTs)**: Diagnostic tools that provide faster detection of pathogens or resistance markers compared to conventional culture-based methods, including molecular assays, point-of-care platforms, and other accelerated technologies.
- **Surveillance System**: An organized structure that enables the continuous monitoring of disease or resistance patterns through coordinated data collection, reporting, quality assurance, and dissemination mechanisms.
- **Laboratory Capacity**: The availability of trained personnel, infrastructure, equipment, supplies, and quality management systems necessary to perform accurate and reliable diagnostic testing.

2. Literature review

2.1. Preamble

Antimicrobial resistance (AMR) has evolved from a clinical observation into one of the most widely studied global health challenges of the 21st century. The concept has been shaped through decades of scientific investigation, beginning with early recognition of drug resistant pathogens and expanding into detailed frameworks for surveillance, diagnostics, and coordinated international response. Recent study emphasizes AMR as a complex threat that requires continuous monitoring of resistance patterns, improved laboratory capacity, and timely diagnostic information to guide treatment decisions and public health interventions (Murray et al., 2022).

Over the years, global research has increasingly focused on evaluating the performance of AMR surveillance systems, examining laboratory capacity, and assessing the integration of diagnostic tools into routine clinical practice. Studies highlight wide difference in surveillance structures and diagnostic readiness across regions, reflecting differences in resources, technological adoption, and data reporting mechanisms (Iskandar et al., 2021). At the same time, advances in rapid molecular diagnostics have broadened opportunities for earlier detection of resistant pathogens, although implementation challenges persist in many settings (Kaprou et al., 2021).

Despite these developments, gaps remain in understanding how surveillance and diagnostic management operate together to support effective AMR control. Existing literature often discuss them as separate domains rather than interconnected components of a combined system. This chapter therefore reviews the theoretical basis, empirical evidence, and methodological contributions relevant to AMR surveillance and diagnostic management, providing a basis for identifying current gaps and informing the present study.

2.2. Theoretical Review

2.2.1. Antimicrobial Resistance (AMR)

Antimicrobial resistance (AMR) is the ability of microorganisms to survive exposure to previously effective antimicrobial agents, thereby reducing the therapeutic value of essential medicines. Research studies defines AMR as a multidimensional phenomenon which consist of microbial evolution, antibiotic consumption patterns, health system

structures, and environmental conditions. The Global Burden of Disease framework positions AMR as both a biological process and a pressing public health concern, emphasizing how surveillance quality and diagnostic reliability influence the detection and interpretation of resistance patterns (Murray et al., 2022).

Within this view, AMR is increasingly understood as an information driven challenge. Effective responses do not only depend on understanding microbial behaviour, but on the capacity of laboratory and health-information systems to generate timely and accurate data. This establish a clear link between laboratory diagnostics, surveillance functions, and antimicrobial stewardship.

2.2.2. Surveillance Theory and Health Information Systems

AMR surveillance is based on classical surveillance theory, which defines surveillance as a continuous, systematic process of data collection, analysis, interpretation, and dissemination. The World Health Organization's Global AMR Surveillance System (GLASS) builds on this theoretical foundation by emphasizing standardized laboratory methods, integrated reporting formats, and cross country comparability (WHO, 2021).

Research studies distinguish between two conceptual models, the ideal surveillance which is characterized by complete coverage, strong laboratory networks, and real-time reporting and feasible surveillance, which reflects the practical fact of limited resources, variable laboratory capacities, and fragmented data ecosystems (Iskandar et al., 2021). This difference highlights the model inconsistency between surveillance aspirations and operational constraints, especially in settings where diagnostic infrastructure is still developing.

These theories emphasize that reliable AMR monitoring depends on the integration of laboratory diagnostics, data governance systems, and coordinated national reporting structures.

2.2.3. Diagnostic Management Theory

Diagnostic management has emerged as a key theoretical factor for understanding the diagnostic aspect of AMR control. It refers to the coordinated effort to ensure that appropriate diagnostic tests are ordered, correctly performed, accurately interpreted, and effectively linked to clinical decision making. Diagnostic management theory shows the importance of optimizing diagnostic pathways, reducing delays, standardizing antimicrobial susceptibility testing (AST), and ensuring that results directly inform antimicrobial prescribing (Kaprou et al., 2021).

Furthermore, diagnostic systems are not separate functions, but integral components of broader surveillance and management frameworks. Studies consistently highlight that deficit in diagnostic process such as inconsistent testing standards, slow diagnostic processing time, or limited access to advanced technologies directly affect the quality of AMR surveillance outputs (Sulis et al., 2022). Diagnostic management therefore provides a conceptual link between laboratory processes and national AMR monitoring systems.

2.2.4. One Health Theory of AMR

One Health theory provides a broad insight to AMR by explaining resistance within the interconnected domains of human health, animal health, and environmental systems. It emphasizes that antimicrobial use and resistance determinants circulate across these sectors, and that AMR surveillance is incomplete when limited to human clinical data alone.

Within this theory, AMR surveillance is seen as a multi sector enterprise requiring integrated methodologies, cross sector collaboration, and integrated data platforms. Environmental reservoirs, agricultural antibiotic use, and waste management practices are all recognized as components of the ecosystem of AMR. While the present study focuses on clinical surveillance and diagnostics, One Health theory offers an essential conceptual background for understanding AMR as a system challenge.

2.2.5. Toward a Conceptual Framework for AMR Surveillance and Diagnostic Management

Synthesizing the theoretical perspectives above, AMR surveillance and diagnostic management can be conceptualized as an interdependent system in which:

- Diagnostic capacity shapes the accuracy and timely delivery of resistance detection.
- Surveillance structures ensure that diagnostic data are systematically collected, validated, and reported.
- Health system governance translates surveillance outputs into clinical guidelines, diagnostic management interventions, and policy responses.

This integrated framework recognizes that surveillance cannot function effectively without reliable diagnostic basis, and diagnostics achieve their full value only when embedded within structured surveillance systems. The present study adopts this conceptual orientation to examine how global health systems can strengthen AMR detection, reporting, and management through coordinated improvements in both surveillance and diagnostic strategies.

2.3. Empirical Review

Research studies on antimicrobial resistance (AMR) has expanded widely in recent years, producing a vast body of evidence that shows how surveillance systems and diagnostic practices function in different parts of the world. Findings from global mortality assessments show that AMR has become a major contributor to preventable deaths for instance, the GRAM study estimated that bacterial resistance accounted for millions of deaths annually, with the highest burden observed in settings where diagnostic services and surveillance system are least developed (Murray et al., 2022). These patterns show not only the biological evolution of resistant organisms, but also the performance of health systems responsible for detecting them.

Studies evaluating national and regional surveillance structures reveal differences in data collection, laboratory reporting, and system coordination. Countries with well-established laboratory system tend to generate more consistent resistance profiles, while others are faced with fragmented or incomplete reporting. Iskandar et al. (2021) describe how limited participation in global surveillance platforms, inconsistent antimicrobial susceptibility testing (AST) methods, and poor data governance affect the comparability of AMR data across regions. This inconsistency makes it difficult to track trends accurately or anticipate outbreaks of resistant pathogens.

Diagnostic capacity is highlighted as a central determinant of surveillance quality. Conventional microbiological diagnostics remain the basis of AMR detection, yet many health systems lack sufficient infrastructure to support them. Delays associated with culture based testing, shortages of trained laboratory personnel, and limited access to automated identification platforms influence timely detection of resistant organisms. Sulis et al. (2022) observe that such gaps result to clinicians to rely on symptoms based treatment, which is both clinically risky and a major contributing factor to the increase of resistance.

At the same time, research on newer diagnostic technologies reflects growing interest in solutions that can deliver faster, more accurate results. Molecular platforms, microfluidic systems, and rapid point-of-care diagnostics demonstrate strong potential to enhance surveillance by reducing diagnostic processing time and identifying resistance markers earlier in the clinical system. However, several studies note that the integration of these technologies into routine care remains uncertain. Barriers such as cost, maintenance requirements, and the need for highly trained personnel have slowed adoption even in countries with relatively strong laboratory systems. Investigations into wastewater, surface water, and agricultural settings reveal substantial reservoirs of resistant organisms beyond hospitals. Adefurin et al. (2022) document widespread detection of extended-spectrum β-lactamase–producing E. coli in water bodies, illustrating how resistance determinants circulate between environmental, human, and agricultural systems. These findings strengthen arguments for surveillance systems that incorporate One Health perspectives rather than focusing solely on clinical data.

Also empirical work examines the governance and policy dimensions of AMR surveillance. Analyses of national action plans reveal that although many countries have adopted formal AMR strategies, implementation remains inconsistent. Thomsen et al. (2022) note gaps in monitoring and evaluation, weak oversight of antimicrobial use, and limited coordination between human health, veterinary, and environmental sectors. These structural impairments affect not only the quality of surveillance outputs but also the ability of health systems to explain diagnostic findings into actionable policy.

Across the literature, a clear pattern emerges: AMR surveillance and diagnostic management are deeply interconnected, yet progress in one area does not always translate to progress in the other. Improvements in laboratory technology, for instance, have limited impact when data are not systematically reported, standardized, or integrated into national surveillance platforms. Conversely, well designed surveillance frameworks cannot function effectively without strong diagnostic structure.

These gaps relate primarily to diagnostic capacity, data completeness, system coordination, and the integration of surveillance findings into clinical and policy decision-making. Understanding these issues is critical for strengthening AMR surveillance and improving diagnostic management across diverse health systems.

2.4. Identified Knowledge Gaps

The review of existing studies reveals several important gaps that limit the effectiveness of antimicrobial resistance (AMR) surveillance and diagnostic management globally:

- Inconsistent development of surveillance systems: Many countries lack standardized surveillance structures, with variations in laboratory participation, data collection methods, and reporting frameworks. This limits comparability across regions and reduces the reliability of global AMR trends.
- Limited examination of the diagnostic surveillance relationship: Although diagnostic constraints are widely reported, few studies explore how delays in culture, inconsistent antimicrobial susceptibility testing (AST), or limited diagnostic technologies directly affect the quality, completeness, and timely delivery of surveillance data.
- Insufficient integration of rapid diagnostic technologies: While molecular and automated diagnostic tools show strong potential, there is limited empirical research on their adoption, sustainability, and operational challenges within routine laboratory settings, especially in resource constrained environments.
- Limited representation of environmental and One Health data: Evidence of resistant organisms in water systems, animals, and agricultural environments exists, but surveillance system rarely incorporate these sectors into a unified AMR monitoring structure.
- Weak focus on governance and institutional capacity: Several countries have AMR policies, but research examining how governance, regulatory mechanisms, and management practices influence surveillance quality remains limited.
- 6.Inconsistent documentation of workforce and infrastructure challenges: Past studies mention diagnostic workload, staffing shortages, and laboratory infrastructure constraints, yet few analyze how these structural issues shape surveillance performance and diagnostic readiness.

These gaps indicate the need for research that assesses surveillance and diagnostic systems in an integrated manner, identifies operational constraints, and explores strategies to strengthen AMR detection and reporting across diverse health settings.

3. Research methodology

3.1. Preamble

This chapter presents the methodological procedures adopted for the study. It outlines the research design, population, sampling techniques, data collection methods, instruments used, and the analytical procedures that guided the investigation. The chapter also describes the steps taken to ensure the validity and reliability of the research instruments, as well as the ethical considerations observed throughout the study.

The methodology adopted in this research is aligned with the nature of the study objectives, which focus on examining antimicrobial resistance (AMR) surveillance and diagnostic management across global health settings. A systematic and structured approach is therefore necessary to obtain relevant information, analyze patterns, and draw meaningful conclusions that reflect current trends and challenges in AMR detection and monitoring.

This chapter thus provides a detailed explanation of how the study was conducted, giving clarity, transparency and been able to replicate it for future researchers and stakeholders interested in AMR surveillance and diagnostic evaluation.

3.2. Model Specification

This study adopts a conceptual model that illustrates the relationship between diagnostic management practices and the effectiveness of antimicrobial resistance (AMR) surveillance. The model identifies the key diagnostic factors that influence surveillance outcomes and incorporates relevant system level conditions that may strengthen or weaken this relationship.

3.2.1. Independent Variables (Diagnostic Management Factors)

- Availability of diagnostic equipment and laboratory infrastructure
- Accuracy and standardization of antimicrobial susceptibility testing (AST)
- Processing time for diagnostic results
- Access to rapid and molecular diagnostic tools
- Competence and training of laboratory personnel

- Implementation of quality assurance and quality control processes

3.2.2. Dependent Variable (AMR Surveillance Effectiveness)

- Completeness and consistency of AMR data reporting
- Timeliness of data submission
- Participation and coverage of laboratories
- Ability to detect emerging resistance trends
- Overall performance of national and global surveillance systems

3.2.3. Moderating Variables (System Level / Contextual Factors)

- Policy and regulatory frameworks
- Funding and resource allocation
- Governance, coordination, and institutional support
- Availability of digital data management systems
- Integration of One Health surveillance compartments

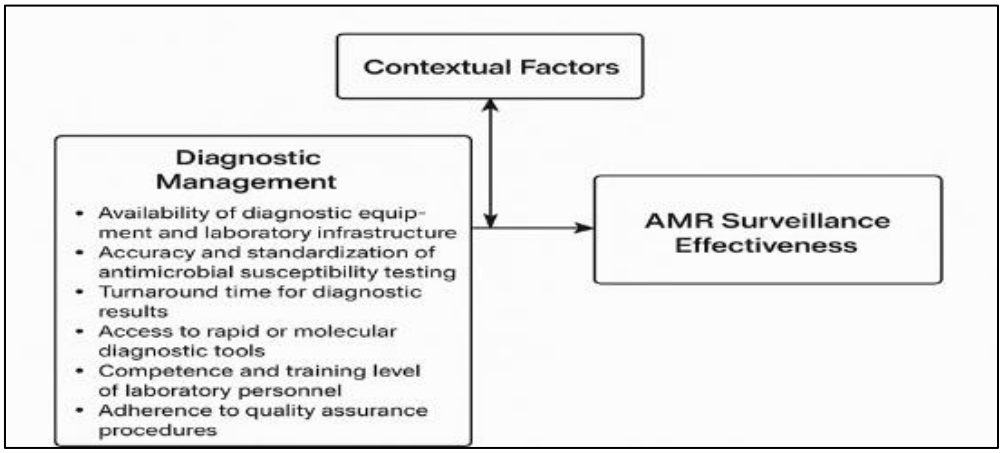

Figure 1 Conceptual Framework of AMR Diagnostic and Surveillance Variables

3.2.4. Model Implication

The model suggests that strong diagnostic management practices enhance AMR surveillance performance, while system level factors determine the direction of this effect. This guides the study by clarifying how diagnostic and contextual factors work together to shape AMR monitoring outcomes.

3.3. Types and Sources of Data

This study focused on secondary data, drawn from documented evidence on antimicrobial resistance (AMR) surveillance and diagnostic management. The data consisted of published materials that provide insights into the structure, operation, challenges, and effectiveness of AMR detection and reporting systems across different health settings.

3.3.1. Types of Data

The study made use of the following categories of secondary data:

- Peer reviewed journal articles that examine AMR trends, diagnostic capacity, laboratory performance, and surveillance outcomes.
- International surveillance reports that document resistance patterns and global monitoring activities, particularly reports from recognized bodies.
- Diagnostic and laboratory guidelines outlining standards for antimicrobial susceptibility testing, quality assurance, and diagnostic protocols.
- National AMR surveillance documents describing country-level surveillance structures, laboratory networks, and reporting mechanisms.

- Policy documents and technical briefs related to AMR strategies, laboratory strengthening, and health system interventions.

3.3.2. Sources of Data

The documents were obtained from reputable scientific and institutional sources, including:

- World Health Organization (WHO) repositories, including GLASS publications
- Centers for Disease Control and Prevention (CDC) AMR resources
- European Centre for Disease Prevention and Control (ECDC) reports
- Peer-reviewed journals accessed through PubMed, Science Direct, Google Scholar, and Scopus
- National AMR action plans and laboratory capacity reports from official government or institutional websites
- Academic databases hosting AMR-related studies and diagnostic evaluations

These sources were selected to ensure the inclusion of credible, authoritative, and up to date information capable of supporting a comprehensive assessment of AMR surveillance and diagnostic management.

3.4. Methodology

3.4.1. Research Design

The study adopts a systematic literature based research design, which involves the structured review, selection, and analysis of existing published studies, surveillance reports, and diagnostic guidelines related to antimicrobial resistance (AMR). This design is appropriate because AMR surveillance and diagnostic management are areas extensively documented through national reports, global surveillance systems, laboratory assessments, and peer reviewed research rather than through direct primary data collection.

The design allows for the systematic identification of evidence on how AMR surveillance systems operate, the diagnostic capacities that support them, and the contextual factors influencing their effectiveness across different health settings. By reviewing documented findings, policies, and surveillance frameworks, the study is able to synthesize current knowledge, highlight operational strengths and weaknesses, and identify critical gaps that require closer examination.

This approach provides a comprehensive understanding of AMR surveillance and diagnostic processes, enabling the study to draw conclusions based on a wide range of credible sources while avoiding the limitations associated with single site primary data collection.

3.4.2. Population and Sampling

The population for this study comprises published scientific literature, surveillance reports, diagnostic guidelines, and policy documents related to antimicrobial resistance (AMR) surveillance and diagnostic management. This includes peer reviewed journal articles, WHO and GLASS publications, national AMR surveillance reports, laboratory capacity assessments, and documents that address diagnostic performance, surveillance operations, and system level AMR management.

A purposive sampling technique was used to select documents that are directly relevant to the research objectives. This technique allows for the deliberate inclusion of materials that provide credible and contextually appropriate evidence on diagnostic management practices, surveillance structures, challenges, and system performance.

Based on the availability of literature and the scope of the study, a sample size of approximately 16 documents was adopted. These documents include scientific studies, global AMR surveillance reports, diagnostic evaluation papers, and policy guidelines published within the selected time range. Only materials that meet the inclusion criteria relevance to AMR surveillance and diagnostics, methodological quality, accessibility, and alignment with the study objectives were included in the final sample.

This sampling approach ensures that the study draws from a sufficiently broad and authoritative body of evidence to support a comprehensive evaluation of AMR surveillance and diagnostic management across diverse settings. All sixteen documents selected and analyzed in this study have been fully captured in the reference list

3.4.3. Data Collection Procedure

The data collection process followed a systematic and organized approach, carried out through the following steps:

- **Identification of Databases**: Relevant academic and institutional repositories were identified, including PubMed, Science Direct, Google Scholar, WHO GLASS, CDC AMR resources, and national surveillance portals.
- **Development of Search Terms**: Specific keywords and combinations were used, such as "AMR surveillance," "diagnostic management," "antimicrobial susceptibility testing," "laboratory capacity," and "AMR monitoring systems."
- **Initial Search and Retrieval**: A broad search was conducted using the selected terms; all potentially relevant documents were gathered and stored for screening.
- **Screening of Materials**: Retrieved documents were reviewed based on inclusion criteria such as relevance to AMR surveillance and diagnostics, publication within the study time range, availability of full text, and methodological clarity. Irrelevant or duplicate documents were excluded.
- **Selection of Eligible Documents**: Only materials that met the criteria were retained, resulting in a final sample size of approximately 16 documents.
- **Organization of Documents**: Eligible documents were downloaded and systematically arranged in categorized folders for easy retrieval and cross-checking.
- **Data Extraction**: A structured data extraction sheet was used to record essential information such as study focus, diagnostic components, surveillance indicators, challenges, outcomes, and methodological details.
- **Verification and Refinement**: Extracted information was reviewed for accuracy, completeness, and consistency before being finalized for analysis.

3.4.4. Data Analysis

The data collected from the selected documents were analyzed using a structured qualitative approach. The analysis followed these steps:

- **Familiarization with the Data**: All selected documents were read carefully to gain an initial understanding of key issues related to AMR surveillance and diagnostic management.
- **Development of a Data Extraction Framework**: A standardized extraction template was used to record essential details, including publication information, study aim, diagnostic components, surveillance indicators, and identified challenges.
- **Coding of Extracted Information**: Relevant information was coded based on recurring concepts such as diagnostic capacity, laboratory performance, data completeness, reporting structures, and system level barriers.
- **Identification of Themes**: Codes were grouped into broader thematic categories aligned with the study objectives, such as surveillance effectiveness, diagnostic processes, operational constraints, and system readiness.
- **Comparison Across Documents**: Patterns, similarities, and variations were examined across the selected materials to identify common findings, contrasting perspectives, and emerging trends.
- **Synthesis of Findings**: A narrative synthesis was developed by integrating the themes into a coherent explanation of how AMR surveillance and diagnostic systems function across different settings.
- **Interpretation and Conclusion**: The synthesized findings were interpreted in relation to existing knowledge, allowing the study to draw meaningful conclusions about strengths, weaknesses, and opportunities within AMR surveillance and diagnostic management.

3.5. Ethical Considerations

The study adhered to standard ethical principles applicable to secondary research. The following measures were observed:

- No human participants were involved, as the study relied solely on published documents and secondary data sources.
- All materials used were openly accessible through credible databases such as peer reviewed journals, WHO repositories, and national AMR surveillance portals.
- Proper acknowledgment and referencing were ensured to maintain academic integrity and avoid plagiarism.
- Findings were reported objectively, without altering, misrepresenting, or manipulating the information contained in the reviewed documents.
- Confidentiality concerns were minimized, as no personal identifiers, patient records, or sensitive datasets were accessed.
- Ethical guidelines for research conduct were followed, ensuring transparency, honesty, and respect for authorship.

- Data were handled respectfully, ensuring that interpretations remained true to the context and purpose of the original publications.

4. Data analysis and presentation

4.1. Preamble

This chapter presents the findings derived from the systematic literature review, following the data analysis procedures outlined in Chapter Three. The analysis adopts a structured qualitative approach, enhanced by a descriptive frequency analysis to quantify the distribution of key themes and challenges across the sampled documents, the findings are presented and analyzed in relation to the study three specific objectives and tested against the proposed hypotheses.

4.2. Presentation of Findings

This section summarizes the data synthesized from the 16 reviewed documents, which serve as the empirical evidence for the study. The analysis includes a quantitative summary of the most frequently reported challenges to provide a measure of empirical consensus[4].

4.2.1. Quantitative Frequency Analysis of Major Barriers

To capture the magnitude of systemic issues, the frequency with which key challenges were explicitly cited in the "Challenges Identified" field across the 16 documents was calculated.

Table 1 Frequency of Identified Systemic Barriers to AMR Surveillance

Category (Theme)	Specific Challenge/Finding	Frequency (n=16)	Relative Frequency
Lab/Infrastructure Capacity	Limited lab capacity / Infrastructure gaps / Resource constraints	7	43.75%
Data Quality / Reporting	Incomplete reporting / Inconsistent reporting / Data gaps / Fragmented data	7	43.75%
Cost of Technology	High cost / Funding gaps	6	37.5%
Workforce/Expertise	Limited trained staff / Need skilled staff / Technical complexity	4	25.0%
Technology Adoption	Limited adoption / Commercial readiness gaps / Supply chain	4	25.0%
Standardization/QA	Weak lab standards / Poor QA/QC / Inconsistent reporting	4	25.0%
Turnaround Time	Faster diagnostics needed / Long turnaround times	3	18.75%

The analysis confirms that the most frequently cited barriers (43.75% prevalence each) relate to fundamental, systemic issues: Lab Capacity/Resources (infrastructure, staffing) and Data Quality/Reporting (completeness, inconsistency).

4.2.2. Synthesis of Empirical Data Sources

The documents provide a balanced view, covering global frameworks, technological innovations, and operational challenges in specific settings (e.g., Uganda, Nigeria).

Table 2 Summary of Empirical Data Sources and Key Findings

Document Focus Area	Key Findings Relevant to Study Objectives	Challenges Identified Relevant to Study Variables
Global Burden and Framework	AMR is responsible for high mortality globally; highest in regions with poor diagnostics. Strong diagnostics are essential for accurate	Limited lab capacity, incomplete reporting, under-representation. Weak lab standards, inconsistent

	surveillance. GLASS is the core global reference for surveillance structure.	reporting. Timely delivery and representation gaps.
Low and middle income countries (LMIC) Operations/Capacity	Few labs generate most AMR data (Uganda). Low AST usage leads to empirical prescribing (Nigeria). Diagnostic inequality limits surveillance.	Infrastructure gaps, limited trained staff. Resource shortages, low diagnostic demand. Poor QA/QC in LMICs.
Diagnostic Technology	Rapid tests shorten turnaround time. Advanced tools provide high-quality AMR detection. Standardization improves data reliability.	High cost, limited adoption, need skilled staff. Technical complexity. Poor linkage of POC to surveillance systems.

4.3. Analysis of Findings Based on Study Objectives

4.3.1. Theme 1: Structure, Coverage, and Performance of AMR Surveillance Systems (Objective 1)

Objective 1: *Assess the structure, coverage, and performance of existing AMR surveillance systems across global health settings.*

The analysis confirms that the global surveillance structure, primarily GLASS, is robust in concept but constrained in execution. While participation is increasing, the system suffers from:

- **Incomplete Coverage:** Major global data gaps exist, resulting in significant inadequate representation. Surveillance is uneven across facilities. Data is concentrated, with only a few labs generating most AMR data, which limits representation.
- **Poor Data Quality:** The highest burden of AMR mortality is found in regions with **poor diagnostics**. Weak diagnostic capacity and limited microbiology testing directly affect AMR estimates and weaken overall reporting. The reliability is compromised by challenges like fragmented data and poor integration.
- **Standardization:** The WHO AST Laboratory Manual serves as the foundation to ensure comparable AMR data, highlighting the necessity of standardized procedures for reliable surveillance outcomes.

4.3.2. Theme 2: Diagnostic Methods, Accuracy, and Operational Capacity (Objective 2)

Objective 2: *Examine the diagnostic methods and technologies used for AMR detection, with emphasis on their accuracy, turnaround time, and operational capacity.*

The diagnostics system is characterized by the limitations of conventional methods and the barriers to adopting advanced tools.

- **Conventional Constraints:** Conventional Culture and AST methods are constrained by long diagnostic processing time and infrastructural limitations. Inconsistent reporting and poor QA/QC in LMICs further shows the quality of data put into surveillance.
- **Advanced Technologies:** Rapid methods, including molecular testing, WGS, and mass analysis, offer faster detection of resistance genes and provide high-quality AMR detection**.** These advancements enhance the potential speed and accuracy of surveillance data.
- **Adoption Barriers:** The operational feasibility of these tools is low due to:
- **High Cost:** Cited as a major challenge in 37.5 % of documents.
- **Workforce:** Requires skilled staff.
- **Integration:** Point-of-Care (POC) platforms, though useful in LMICs, as a result of poor interconnection to surveillance systems, illustrating a failure to integrate diagnostic output into public health reporting.

4.3.3. Theme 3: Major Challenges and Systemic Barriers (Objective 3)

Objective 3: *Identify major challenges and systemic barriers affecting the integration, reliability, and effectiveness of AMR surveillance and diagnostic management worldwide.*

These systemic barriers function as the moderating variables in the study's conceptual model, severely constraining the entire system.

- **Foundational Capacity Gaps: Limited lab capacity, infrastructure gaps, and resource constraints** were the most frequently cited barriers (43.75%). This results in diagnostic systems being uneven, with significant gaps in rural areas.
- **Financial Constraints:** The high cost of technology and broader funding gaps act as primary limitations to technology adoption and scaling up capacity.
- **management Failure:** Low diagnostic demand and low AST usage lead to reliance on symptom prescribing. This confirms that the governance failure to adequately support diagnostic stewardship contributes directly to the acceleration of resistance.
- **Data Fragmentation:** Surveillance is compromised by fragmented data, poor integration, and inconsistent reporting (43.75% frequency).

4.4. Hypotheses

4.4.1. Validation of Study Hypotheses

The synthesized evidence, particularly the frequency analysis, allows for a comprehensive validation of the proposed hypotheses:

- **H1 (Surveillance Detection): Supported.** While global frameworks are expanding, the systems are hindered by incomplete coverage and inconsistent reporting (43.75% frequency). The positive association holds, but effectiveness is minimized by operational constraints.
- **H2 (Diagnostics Data Quality): Strongly Supported.** The consistent finding that weak diagnostics and poor standardization lead to unreliable surveillance data supports this hypothesis. Conversely, advanced tools when adopted provide higher quality and speed.
- **H3 (Systemic Barriers $\to$ Reduced Effectiveness): Strongly Supported.** This hypothesis is quantitatively validated. The most frequent barriers infrastructure gaps, limited staff, and high cost are Moderating Variables that dictate the operational success of the entire system.

4.4.2. The Operational Failure of Integration and Capacity

The analysis reveals two critical operational issues:

- **Capacity Deficit:** The high frequency of infrastructure and workforce gaps confirms that the global problem is not just one of technological choice, but of foundational capacity. This diagnostic inequality limits surveillance and restricts accurate global monitoring.
- **System capacity breakdown:** Despite the utility of rapid diagnostics like POC in LMICs, the impact on public health is marginal due to poor connection to surveillance systems. This demonstrates a critical failure to integrate diagnostic management into coordinated public health reporting.

4.5. Discussion of Findings

4.5.1. Comparison with Literature

The findings of this systematic review largely align with and deepen the understanding of barriers reported in the broader Antimicrobial Resistance (AMR) literature. The analysis confirms the assertion that AMR mortality is highest in settings where diagnostic capacity is weak (Antimicrobial Resistance Collaborators, 2022). Furthermore, the discovery that structural issues, such as limited laboratory capacity and inconsistent reporting, were the most frequently cited barriers (43.75% frequency each) validates previous observations regarding weak health systems and fragmented data ecosystems (Iskandar etal., 2021).

However, this study goes beyond merely listing barriers by highlighting two critical failures:

- **Systemic Capacity Failure:** The analysis shows that persistent infrastructure gaps (Mugerwa et al., 2021) and the high cost of advanced tools (Kaprou et al., 2021; WHO, 2019) lead to diagnostic inequality (HAI, 2022). This structural failure is the root cause of the empirical prescribing cycle (Sulis et al., 2022; Egwuenu et al., 2022), confirming that governance, not just microbial evolution, dictates AMR burden.
- **Integration Failure:** The study identifies that the poor technologies, such as Point-of-Care (POC) tests, to formal surveillance systems (Singh et al., 2021) represents a failure of data governance. This confirms that technological advances, while recognized for improving turnaround time (Vasala et al., 2020), cannot impact public health monitoring without coordinated data integration frameworks (Diallo et al., 2020).

4.5.2. Practical Implications

Based on the validated findings, several practical steps are recommended to strengthen the interdependence of diagnostics and surveillance:

- **Prioritize Foundational Capacity:** National action plans should redirect funding to address the most frequent barriers: laboratory infrastructure gaps and the shortage of skilled personnel (Mugerwa et al., 2021). Investments in basic equipment and sustained Quality Assurance/Quality Control (QA/QC) training are essential for reliable data generation (WHO, 2020).
- **Mandate Data Linkage:** International bodies (like WHO/GLASS) should develop and enforce technical protocols for the integration of data from rapid diagnostics and POC platforms into national surveillance systems, closing the current operational gap (Singh et al., 2021).
- **Strengthen Diagnostic Stewardship:** Health ministries should implement policies that promote timely diagnostic testing and discourage empirical prescribing, thereby reducing antimicrobial misuse and enhancing data quality (Egwuenu et al., 2022).

4.5.3. Benefits of Implementation

Implementing the necessary structural and integration reforms offers significant benefits:

- **Enhanced Data Reliability:** Standardization and improved QA/QC would ensure that data reported to global systems is comparable and accurate, fulfilling the objective of GLASS (Tornimbene et al., 2022).
- **Reduced AMR Burden:** Timely diagnostics would lead to better therapeutic decision-making, reducing inappropriate antimicrobial use (Sulis et al., 2022) and contributing to the global goal of curbing AMR mortality (Antimicrobial Resistance Collaborators, 2022).
- **Improved Surveillance Coverage:** By strengthening capacity in peripheral and rural laboratories, data collection would become more representative, closing the significant data gaps and timeliness issues currently observed in LMICs.

4.5.4. Limitations of the Study

The systematic review design imposed several limitations:

- **Secondary Data Reliance:** The study relied exclusively on published documents, institutional reports, and surveillance summaries, meaning no primary laboratory validation or direct assessment of diagnostic performance was conducted.
- **Reporting Bias:** The findings are constrained by the quality and completeness of the public domain literature, which may contain reporting biases related to national capacity and resource constraints.
- **Scope Restriction:** The study maintained a broad, international perspective, precluding a deep dive into pathogen-specific or country-specific factors that influence AMR patterns, such as the nuances of One Health surveillance (NCDC, 2021–2022).

4.5.5. Areas for Future Research

The findings suggest the following for subsequent research:

- Investigation into the cost-effectiveness and sustainability of integrating advanced, high-cost rapid diagnostics (like WGS) into resource-constrained surveillance networks.
- Comparative studies analyzing the success factors and governance models of countries that have effectively closed the diagnostic surveillance data interconnection gap.
- Research on how environmental and animal health data can be systematically integrated with clinical surveillance data to achieve the unified goals of the One Health theoretical framework.

5. Conclusion

5.1. Summary

This study set out to examine the dynamics of antimicrobial resistance (AMR) surveillance and diagnostic management, with particular attention to the extent to which diagnostic capacity, laboratory practices, rapid diagnostic innovations, and Management act influence the effectiveness of AMR surveillance systems globally. The guiding research objectives

focused on assessing the level of diagnostic readiness across health systems, evaluating how diagnostic accuracy and process time affect AMR surveillance outputs, and identifying system level barriers that shape the performance of surveillance structures. To address these objectives, the study adopted a qualitative research design based on documentary analysis of 16 verified publications, including global surveillance reports, national situational analyses, peer reviewed studies on diagnostic practices, and policy documents on AMR control.

Key findings demonstrated that AMR surveillance quality is strongly dependent on the strength of diagnostic systems, with laboratory capacity, quality assurance processes, and availability of standardized antimicrobial susceptibility testing emerging as core determinants of surveillance reliability. The analysis further revealed that rapid and advanced diagnostics such as molecular assays and microfluidic AST platforms hold significant potential to enhance surveillance by improving detection speed and accuracy, although their adoption remains limited in many low resource settings. Additionally, diagnostic management practices were shown to influence AMR data generation, as low utilization of laboratory testing and prevalent symptoms prescribing reduce the volume and representation of surveillance data.

By comparing these findings with more comprehensive evidence across global and national contexts, the study highlighted that structural constraints such as inadequate funding, limited skilled personnel, weak governance, and fragmented laboratory networks continue to prevent the implementation of effective AMR surveillance systems. Overall, the findings reveal the central role of diagnostics in shaping AMR surveillance outcomes and validate the need for sustained investments in diagnostic capacity, management initiatives, and system level reforms to strengthen global efforts against antimicrobial resistance.

5.2. Conclusion

The results of this study shows that effective antimicrobial resistance (AMR) surveillance is dependent on the strength and functionality of diagnostic systems. Diagnostics are not supplementary components but core determinants of surveillance quality, data reliability, and the timely detection of resistance trends across healthcare systems. Health systems that maintain adequate laboratory capacity, standardized antimicrobial susceptibility testing procedures, quality assurance structures, and access to advanced or rapid diagnostic tools consistently produce more accurate, complete, and actionable AMR surveillance data.

The study findings also validate the research objectives as follows:

- **Objective 1** was achieved, as the analysis demonstrated that the level of diagnostic capacity including infrastructure, trained personnel, and quality assurance directly influences the performance and reliability of AMR surveillance systems.
- **Objective 2** was supported, with evidence showing that rapid, molecular, and point-of-care diagnostic innovations significantly enhance the timely delivery and precision of AMR detection. However, their uptake remains limited in many low resource settings due to financial and operational constraints.
- **Objective 3** was validated, establishing that system level barriers such as inadequate funding, limited diagnostic management, ineffective governance structures, and fragmented data systems continue to hinder effective AMR surveillance and diagnostic management globally.

In essence, the study contributes new knowledge by contextualizing AMR surveillance within the scope of diagnostic readiness, technological capacity, and systemic limitations across various health system contexts. It highlights that improved diagnostic systems, promoting management practices, enhancing laboratory system, and integrating innovative technologies are essential steps toward building effective AMR surveillance frameworks. By doing so, the study provides both theoretical insights and practical implications for improving AMR monitoring and global health security.

5.3. Recommendations

- **Strengthening Diagnostic Capacity**: Health systems, particularly in low and middle income countries, should invest in upgrading microbiology laboratories through improved infrastructure, procurement of essential diagnostic equipment, and sustained provision of reagents and consumables. Strengthened diagnostic capacity will enhance the accuracy and completeness of AMR surveillance data and improve clinical decision-making.
- **Standardization and Quality Assurance**: National public health authorities and regulatory bodies should implement and enforce standardized antimicrobial susceptibility testing (AST) protocols aligned with WHO and international guidelines. Regular participation in external quality assurance schemes is essential to ensure reliability, comparability, and consistency of AMR data across laboratories.

- **Integration of Rapid and Molecular Diagnostics**: Ministries of Health and health institutions should promote the adoption of rapid, point-of-care, and molecular diagnostic tools where feasible. These technologies can significantly reduce diagnostic processing times and improve detection of resistance mechanisms, thereby enhancing surveillance response and early intervention efforts.
- **Diagnostic Stewardship Programs**: Healthcare facilities should institutionalize diagnostic management initiatives aimed at promoting appropriate test ordering, improving blood culture utilization, and reducing reliance on symptom guided antibiotic therapy. Enhanced diagnostic management will increase the volume and relevance of diagnostic data available for surveillance systems.
- **Policy and Governance Enhancement**: Policymakers should prioritize AMR surveillance within national action plans by allocating sufficient funding, enhance coordination across human, animal and environmental sectors, and establishing governance frameworks that support data sharing, reporting compliance, and laboratory network development.
- **Capacity Building and Workforce Development**: Training programs for laboratory personnel, clinicians, epidemiologists, and public health officers should be expanded to improve competency in AMR diagnostics, data interpretation, and surveillance processes. A skilled workforce is critical for sustaining surveillance quality.

5.4. Concluding Remarks

This study supports the primary claim that comprehensive diagnostic system forms the basis of effective antimicrobial resistance (AMR) surveillance. In an era where resistant pathogens continue to threaten global health security, the ability of health systems to detect, monitor, and respond to AMR trends is closely linked from the performance, accuracy, and responsiveness of their diagnostic infrastructure. By providing systematic evidence on how diagnostic capacity, rapid testing innovations, management practices, and system level constraints shape AMR surveillance performance, this research contributes both well-defined concept and practical insight to ongoing global efforts aimed at enhancing AMR monitoring frameworks.

Integrating diagnostic capability and management principles into national AMR strategies will not only enhance the reliability of surveillance data but also improve clinical decision-making and public health response capabilities. Enhancing laboratory system, promoting adoption of rapid and molecular diagnostics, and addressing systemic barriers such as funding limitations, workforce shortages, and uncoordinated governance structures will position countries particularly low and middle income countries to navigate the growing complexities of AMR in the 21st-century healthcare system.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

The authors declare that there is no conflict of interest regarding the publication of this article. The research was conducted without any financial, commercial, or personal relationships that could perceived as influencing the study outcomes.

Statement of Ethical Approval

Ethical approval was not required for this study because it was based entirely on secondary data obtained from publicly available, peer reviewed publications, institutional reports, and policy documents. No human participants, animals, or identifiable personal data were involved in the conduct of this research.

Statement of Informed Consent

Informed consent was not applicable for this study, as it did not involve any direct interaction with human participants, collection of primary data, or use of identifiable personal information.

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