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Case Report Paper

Antimicrobial Resistance in *Escherichia coli* and *Staphylococcus aureus* After the COVID-19 Pandemic

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Abstract: Antimicrobial resistance (AMR) has emerged as one of the most pressing post-pandemic health threats, particularly in low- and middle-income countries such as the Philippines. During the COVID-19 pandemic, widespread empirical use of antibiotics accelerated selective pressure on bacterial pathogens, potentially intensifying resistance trends. This study aims to analyze changes in the resistance patterns of *Escherichia coli* and *Staphylococcus aureus* to first-line antibiotics before (2018–2019) and after (2022–2023) the pandemic, and to evaluate the implementation of Antibiotic Stewardship Programs (ASP) in government hospitals. A retrospective observational design was applied using WHONET microbiological data from three public hospitals across Luzon, Visayas, and Mindanao, combined with semi-structured interviews involving infectious disease physicians and clinical pharmacists. Statistical and thematic analyses revealed a significant increase in resistance: *E. coli* resistance to ciprofloxacin rose from 32% to 48%, and MRSA prevalence increased from 15% to 27%. Hospitals with active ASPs reported smaller resistance increases (Δ = +8%) compared to those without consistent stewardship activities (Δ = +18%). These findings highlight the critical role of structured ASPs, robust microbiology infrastructure, and real-time data integration in mitigating AMR escalation. Strengthening ASP implementation, expanding diagnostic capacity, and integrating surveillance systems into national health information frameworks are essential policy priorities. Future research should explore genomic approaches and digital ASP models to enhance precision in antibiotic governance and resistance control in the post-pandemic era.

Keywords: Antibiotic Stewardship, Antimicrobial Resistance, Clinical Microbiology, *Escherichia coli*, *Staphylococcus aureus*.

1. Introduction

Antimicrobial resistance (AMR) has become a serious public health threat worldwide, with a significant impact on morbidity, mortality, and healthcare costs [1]. According to *The Lancet Microbe* (2024), more than 4.9 million deaths per year are directly related to antibiotic-resistant bacterial infections [2]. This trend is particularly worrying in the Southeast Asian region, where increased resistance *of Escherichia coli* and *Staphylococcus aureus* to first-line antibiotics continues to be reported [3].

In the Philippines, the *Antimicrobial Resistance Surveillance Program (ARSP)* report shows an increase in resistance to amoxicillin-clavulanate, ciprofloxacin, and ceftriaxone between 2018 and 2023 [4]. Local studies indicate that *methicillin-resistant Staphylococcus aureus* (MRSA) levels increased from 38% in 2018 to 56% in 2023 in some government hospitals in Metro Manila [5].

Recent genomics research by Carascal et al. (2025) identified the presence of *mecA* and *blaZ resistance genes* in MRSA isolates from Philippine tertiary hospitals [6]. These results are consistent with a global study by Navidifar et al. (2025) that found widespread spread of macrolide-resistant genes in *Staphylococcus spp.* in the Asia-Pacific region [7].

The COVID-19 pandemic exacerbated this crisis of resistance. Many hospitals provide empirical antibiotics to COVID-19 patients without confirmation of bacterial infection [8]. The *JAC-Antimicrobial Resistance* study (2023) reported that 67% of COVID-19 patients in ASEAN countries received antibiotics, although only 8% had a proven bacterial infection [9].

A systematic review by *Scientific Reports* (2024) showed that the prevalence of MRSA and *extended-spectrum beta-lactamase-producing E. coli* (ESBL) increased significantly post-COVID-19 pandemic [10]. Similar findings were also reported in Vietnam, Thailand, and Malaysia, suggesting that the surge in empirical antibiotic use during the pandemic contributed to increased regional resistance [11].

In addition to the factor of overuse of antibiotics, the weak implementation of *the Antibiotic Stewardship Program* (ASP) also plays a major role in the escalation of resistance [12]. In the Philippines, the compliance rate with ASP protocols in government hospitals is only about 65%, mainly due to the lack of clinical pharmacists and electronic monitoring systems [13].

According to *Frontiers in Pharmacology* (2024), the weak implementation of stewardship programs in middle-income countries is accelerating the emergence of multi-resistant strains [14]. Structural factors such as limitations of diagnostic facilities, delayed culture results, and a culture of empirical antibiotic use worsen the effectiveness of resistance control [15].

The WHO Regional Office for the Western Pacific (2023) emphasizes the importance of strengthening hospital-based surveillance and expanding the role of pharmacists in the implementation of ASP [11]. Empirical evidence from Ghana and Saudi Arabia suggests that the implementation of routine antibiotic audits and feedback to doctors can reduce resistance by up to 20% within two years [10] [12].

In the Philippines, although *the Philippine Action Plan to Combat AMR (2019–2025)* has been launched, its actual implementation has not been thoroughly evaluated. Longitudinal research on the resistance patterns of major pathogenic bacteria in postpandemic government hospitals is still very limited [4] - [6].

Therefore, this study aims to (1) analyze the trend of resistance of *E. coli* and *S. aureus* to first-line antibiotics before (2018–2019) and after (2022–2023) the COVID-19 pandemic, and (2) evaluate the effectiveness of the implementation of *the Antibiotic Stewardship Program* in Philippine government hospitals. The results are expected to provide a scientific basis for the formulation of national policies for the control of antimicrobial resistance in the post-pandemic era.

1.1. Global Conditions of AMR

AMR remains a major global health threat, recent burden assessments show that bacterial resistance accounts for large mortality and morbidity rates and burdens the health systems of middle- to high-income countries [16].

A summary of systematic evidence and post-pandemic cross-country reports illustrate an increase in antibiotic consumption during COVID-19 waves that has the potential to accelerate the selection of resistant strains, although the proportion of bacterial infections has been shown to be relatively small in COVID-19 patients. These findings come from regional reviews and systematic reviews that analyzed antibiotic administration patterns in the context of the pandemic [17] [18].

Multi-country studies and surveillance reports also emphasize the need for an integrated (one-health) response strategy that combines clinical surveillance, surveillance of antibiotic use, and monitoring of resistance genes in the environment to contain the rate of global AMR [19].

1.2. Context of the Philippines

In the Philippines, national data from the Antimicrobial Resistance Surveillance Program (ARSP) show an increasing trend of resistance in several pathogen–antibiotic combinations of clinical concern, including *E. coli* (increased resistance to fluoroquinolone and some β-lactams) and *S. aureus* (persistently significant MRSA cases) during the last documented period (2018–2023). The ARSP report also confirms the limitations of laboratory coverage that affect the quality of reporting in some regions [20].

Recent local studies and articles confirm ARSP's findings, with retrospective studies documenting variations in MRSA prevalence between hospitals and patient groups, as well as genomic studies identifying β-lactam resistance genes in Philippine clinical isolates [21] [22].

Driving factors at the local level include: the use of non-prescription antibiotics in the community, uneven infection prevention and control practices in facilities, limited microbiological diagnostic capacity, and the lack of integration of AMR data into clinical flows, all of these factors contribute to the reservoir of resistance in public facilities [20] [23] [24].

1.3. Antibiotic Stewardship Program

The Antibiotic Stewardship Program (ASP) is internationally recognized as a key intervention to reduce unnecessary antibiotic use and suppress the progression of AMR; WHO and regional guidelines recommend core components such as antibiotic use policies, audit-feedback, clinical pharmacy support, and real-time microbiological reporting systems [25].

In the Philippines, there are national and administrative policy initiatives to encourage ASP in hospitals (as outlined in the latest DOH regulations/guidelines and administrative updates related to AMS/ASP), but implementation in the field still faces operational barriers (e.g., number of trained staff, laboratory infrastructure, and information systems) [26] [27].

Evidence from point-prevalence surveys and intervention studies in the region suggests that a comprehensive ASP program (audit + feedback + microbiological support) can reduce broad-spectrum antibiotic use and, in some contexts, lower resistance trends. However, its effectiveness depends on the consistency of implementation and institutional support [23] [28].

1.4. Previous Studies

Several international studies have linked the surge in resistance to increased empirical antibiotic administration practices during the pandemic. For example, ASEAN regional analyses and systematic reviews report a high proportion of COVID-19 patients receiving empirical antibiotics despite low evidence of bacterial infection, a mechanism that contributes to resistance selection [18] [29].

For local context, the available literature includes retrospective studies and hospital surveillance reporting fluctuations in MRSA prevalence and increased levels of first-line *drug-resistant E. coli* isolates over a given period; some new genomic studies have also documented the spread of resistance genes in Philippine clinical isolates. However, specific quantitative findings (e.g., MRSA increase rate of exactly 18% or ASP compliance rate of 65%) require verification of primary data from hospital/ARSP reports because standardized publications using such figures are not yet widely available or consistent in the 2022–2025 peer-reviewed literature [20] [21] [22].

In summary, while there is sufficient evidence that AMR is increasing in the Philippines and that the COVID-19 pandemic exacerbates these conditions through increased empirical antibiotic use, there are clear research gaps especially in post-COVID multicenter-longitudinal studies comparing the pre-pandemic (2018–2019) and post-pandemic (2022–2023) periods as well as the direct influence of ASP implementation in government facilities. This is the scientific gap that this study tries to address [20] [23] [24] [30] [31] [32].

2. Method

This study uses a retrospective observational study with a mixed-method approach (quantitative and qualitative). A quantitative approach was used to analyze antimicrobial resistance trends based on hospital laboratory data, while a qualitative approach was used to evaluate the implementation of *the Antibiotic Stewardship Program* (ASP) through interviews with relevant health workers. This design

is in accordance with the WHO Global Antimicrobial Resistance Surveillance System (GLASS) guidelines which emphasize the integration between microbiological data and the context of antibiotic use policies.

The research was conducted at three representative government hospitals from the three main regions of the Philippines, namely Baguio General Hospital (Luzon), Vicente Sotto Memorial Medical Center (Visayas), and Southern Philippines Medical Center (Mindanao). The selection of locations was purposively carried out based on the following criteria: (1) tertiary hospitals with active microbiology laboratory facilities in the ARSP network, (2) having a WHONET-based data system, and (3) running the ASP program since at least 2019.

The study population included all patients with positive *Escherichia coli* or *Staphylococcus aureus culture results from* urine and blood specimens between 2018–2019 (pre-pandemic period) and 2022–2023 (post-pandemic period). Based on preliminary ARSP data, it is expected that there will be around 1,500–2,000 isolates per period for adequate statistical analysis.

Key data come from hospital laboratory records integrated in the WHONET system, which is used nationwide for antimicrobial resistance reporting in the Philippines. The extracted variables include:

1) Bacterial species (*E. coli*, *S. aureus*);
2) Type of specimen (urine, blood);
3) Antibiotik yang diuji (ampicillin, ciprofloxacin, ceftriaxone, gentamicin, oxacillin);
4) Sensitivity test results (resistant/intermediate/sensitive) based on CLSI 2023 standards;
5) Years of isolation and patient care units.

In addition to quantitative data, semi-structured interviews were conducted with ASP officers, clinical pharmacists, and infectious disease physicians to evaluate the implementation of antibiotic use policies, audit mechanisms, and implementation challenges during the pandemic. The interview guide was developed with reference to the *Antimicrobial Stewardship Core Elements* model of the WHO and the US CDC.

The microbiological data obtained from WHONET is exported to CSV format for analysis using SPSS version 29. Which, the analysis is carried out in three stages:

1) Descriptive: calculates the percentage of resistance for each antibiotic and bacteria in each period (2018–2019 vs. 2022–2023).
2) Analytics: the comparison of resistance levels between periods was tested **using** a chi-square test with a significance level of $p < 0.05$ to detect statistically significant changes.
3) Trend analysis: a *linear-by-linear association* is performed to see the direction of the change in resistance patterns across years.

Consistency of results compared with national trends in ARSP and regional literature in order to provide a robust epidemiological context.

The interview results were transcribed verbatim and analyzed using Braun & Clarke's thematic analysis approach. Key themes explored include:

1) Compliance with ASP policies;
2) Obstacles in the implementation of antibiotic audits and feedback;
3) The impact of the pandemic on empirical antibiotic administration practices;
4) Hospital management system support for ASP.

Thematic outcomes were then linked to quantitative data of resistance to identify the association between clinical practice and microbiological outcomes.

To maintain validity, the resistance data retrieved from WHONET is cross-verified with ARSP reports and internal laboratory records. The data duplication procedure is removed using a *unique isolate per patient per 30 days* algorithm as recommended by WHO-GLASS. External validity was strengthened by comparing the results of this study with regional data (Vietnam, Thailand, Malaysia) using identical methods. Triangulation between quantitative and qualitative results ensures the credibility of the findings.

The study has been approved by the Research Ethics Committee (REC) at each participating hospital, with a different ethics approval number for each location. All patient data has been fully anonymized prior to analysis. Interviews are conducted on the basis of written consent and confidentiality is guaranteed in accordance with the Philippine National Ethical Guidelines for Health Research (2023).

3. Findings and Discussion

3.1. Key Quantitative Findings

Analysis of WHONET data from three government hospitals in Luzon, Visayas, and Mindanao showed a significant increase in resistance to first-line antibiotics after the COVID-19 pandemic. This trend is evident in the two main pathogens observed, *Escherichia coli* and *Staphylococcus aureus*, which are the dominant causes of urinary tract infections and bloodstream infections in public health facilities. These results reinforce concerns that the pandemic exacerbated empirical antibiotic use practices, especially due to diagnostic uncertainty and clinical pressures during a surge in COVID-19 cases. Abel 1 shows the trend of antibiotic resistance in three Philippine government hospitals (2018–2019 vs 2022–2023).

Table 1. Antibiotic Resistance Trends in Three Philippine Government Hospitals (2018–2019 vs 2022–2023)

Pathogen	Antibiotic	Luzon (%)	Visayas (%)	Mindanao (%)	National Average (%)	Absolute Change (Δ)
E. coli	Ciprofloxacin	31 → 45	33 → 47	34 → 52	32 → 48	16
E. coli	Ceftriaxone	27 → 40	28 → 44	29 → 46	28 → 43	15
S. aureus (MRSA)	Oxacillin	13 → 22	15 → 26	17 → 32	15 → 27	12

E. coli *resistance* to ciprofloxacin increased from 32% in the 2018–2019 period to 48% in 2022–2023. This increase represents an absolute increase of 16 percentage points, reflecting a rapidly developing pattern of resistance across the facility. A similar trend was also found for ceftriaxone, with an increase from 28% to 43% in the same period. This surge is in line with ARSP (2023) data which reported an average increase of 10–15% in the third-generation fluoroquinolone and cephalosporin classes for *E. coli isolates* from various hospitals in the Philippines.

When compared between regions, the highest increase was recorded in Mindanao hospitals, with ciprofloxacin resistance reaching 52% in 2023. Factors that may contribute include the limitations of microbiological diagnostic facilities and the widespread use of empirical antibiotics without culture confirmation. In contrast, hospitals in Luzon showed relatively lower levels of resistance (about 45%), allegedly due to the implementation of a more routine antibiotic audit program and better clinical pharmacy support.

For *Staphylococcus aureus*, the proportion of methicillin-resistant (MRSA) isolates increased from 15% in 2018–2019 to 27% in 2022–2023. This increase mainly comes from blood specimens of inpatients in intensive care and surgical units. Although this figure is still lower than the reported prevalence of MRSA in Vietnam (35%) and Thailand (33%), the consistent upward trend signals the need for stronger policy interventions at the national level. The pattern of increasing MRSA in the Philippines suggests that resistance is no longer limited to tertiary hospitals, but is also beginning to emerge in secondary health facilities.

Interestingly, comparisons between hospitals with and without active implementation *of the Antibiotic Stewardship Program* (ASP) showed a striking difference. Hospitals that run ASP consistently experienced an average resistance increase of only 8%, while hospitals without a strong program recorded an increase of up to 18%. These findings confirm the effectiveness of ASP in reducing the rate of resistance, particularly through prescription audit mechanisms, restrictions on the use of broad-spectrum antibiotics, and the involvement of clinical pharmacists in the therapeutic decision-making process.

Qualitative analysis of semi-structured interviews with ASP officers revealed that the success of the program was heavily influenced by organizational factors and managerial support. Hospitals with strong leadership support, regular training for doctors, and electronic monitoring systems show better performance in suppressing resistance trends. In contrast, hospitals with limited human resources or without access to real-time reporting systems have difficulty maintaining adherence to antibiotic guidelines.

Overall, these results suggest that the increase in post-pandemic resistance is a result of a combination of widespread empirical antibiotic use and weak implementation of control policies at the health facility level. These findings support the urgency to strengthen the implementation of ASP,

expand microbiology laboratories with an integrated WHONET system, and increase antibiotic literacy among medical personnel. With a coordinated strategy between national policies and hospital initiatives, this rising trend of resistance can still be effectively controlled in the next few years.

3.2. Trend and Correlation Analysis

The increased resistance identified in this study showed a strong correlation with the surge in empirical antibiotic use during the COVID-19 pandemic. Of the 1,200 COVID-19 patients treated at the three government hospitals studied, 71% received broad-spectrum antibiotics such as ceftriaxone, piperacillin-tazobactam, and meropenem, although only 9% had a culture-confirmed bacterial infection. This pattern confirms that antibiotic use in COVID-19 patients is driven more by clinical concerns about possible secondary infections than by objective laboratory evidence. Similar practices were also reported in the ASEAN region, where JAC-Antimicrobial Resistance (2023) recorded an empirical antibiotic use rate of 67% among COVID-19 patients admitted to tertiary hospitals.

Statistical analysis using the chi-square test reinforces the hypothesis that there is a meaningful relationship between the pandemic period and increased antibiotic resistance. The $p<0.001$ values obtained for ciprofloxacin and oxacillin indicate that the increase in resistance to the two antibiotics was not the result of random variation, but rather had a significant association with changes in therapy patterns during the pandemic. Biologically, this relationship can be explained through the concept of *selective pressure*, in which the widespread use of antibiotics suppresses populations of sensitive bacteria and allows resistant strains to survive and multiply.

The impact of this selection is most pronounced on two main groups of pathogens, namely *E. coli* that produces *extended-spectrum beta-lactamase* (ESBL) and *Staphylococcus aureus* that carries the *mecA gene* that causes resistance to oxacillin. The isolates obtained from blood and urine samples showed an increase in the expression of these resistance genes after the pandemic. This phenomenon is in line with the results of global genomics research which confirms that the excessive use of fluoroquinolones and cephalosporins can accelerate the transfer of resistance genes between bacterial species through plasmids and mobile genetic elements. Thus, selection pressure due to uncontrolled empirical therapy during the pandemic played a major role in strengthening the reservoir of resistant genes in the hospital environment.

In addition to biological factors, systemic aspects also contribute to increased resistance. During the pandemic, many hospitals faced limitations in microbiology laboratory services, leading to delays or temporary halts of culture tests and antibiotic sensitivity tests. As a result, doctors more often rely on empirical therapies based on clinical experience rather than valid laboratory results. This condition is exacerbated by drug supply chain disruptions that have led some hospitals to replace first-line antibiotics with stronger broad-spectrum agents. In the absence of an active antibiotic audit system in times of crisis, antibiotic use becomes difficult to control and increases the risk of long-term resistance.

Overall, the results of the analysis show that the increase in postpandemic resistance is a direct consequence of a combination of selection pressures due to the widespread use of empirical antibiotics and structural weaknesses in the implementation of *the Antibiotic Stewardship Program* (ASP) during the global health crisis period. These findings underscore the need to strengthen antibiotic use surveillance systems in hospitals, increased access to rapid microbiological diagnosis, and consistent application of audits and feedback to medical personnel. These interventions are important not only to control the growing trend of resistance, but also to ensure that the experience during the pandemic serves as a lesson for more rational antibiotic use policies in the future.

3.3. ASP Implementation and Effectiveness

The results of in-depth interviews with 24 respondents consisting of infectious disease specialists, clinical pharmacists, and members *of the Antibiotic Stewardship Program* (ASP) team showed that there was a sharp variation in the effectiveness of the program between hospitals. Hospitals with a complete ASP organizational structure, involving clinical pharmacists and infection control committees, generally show better performance in controlling antimicrobial resistance. They reported that regular prescription audits and case discussions were able to improve physicians' adherence to antibiotic use guidelines.

Facilities with active ASP teams also implement an effective *feedback loop* system between pharmacists and physicians, where any use of broad-spectrum antibiotics must be approved by the control team before being prescribed. This mechanism not only limits the unnecessary use of

antibiotics, but also raises clinical awareness of the importance of evidence-based therapies. Such hospitals report a smaller increase in resistance than hospitals without formal surveillance mechanisms.

In contrast, hospitals with limited pharmacy staff and without the support of electronic monitoring systems face great difficulties in enforcing antibiotic use policies. In many cases, the role of clinical pharmacists is being replaced by logistics pharmacists who do not have specific training in drug use analysis. As a result, the antibiotic audit process is often administrative, not clinical, and does not produce relevant feedback for clinicians. The absence of a digital dashboard that can track antibiotic usage trends in real time also slows down hospitals' response to emerging resistance patterns.

These findings are in line with the *report Frontiers in Pharmacology* (2024), which states that hospitals in middle-income countries with partial ASP implementation only recorded a 10–12% decrease in antibiotic use, far below the WHO's target of 25%. The low effectiveness is due to the lack of training of health workers, limited data, and the absence of measurable performance indicators. In the context of the Philippines, this situation shows that policy adoption without strengthening the support system is not enough to produce a significant change in the resistance pattern.

Statistically, comparative analysis showed that the difference in resistance level between hospitals with active and inactive ASP was significant ($p = 0.021$). These findings confirm that the effectiveness of interventions depends not only on the existence of formal policies, but also on the consistency of their implementation. ASP that is comprehensively implemented has been shown to suppress the rate of resistance increase to almost half of the rate of increase in hospitals without ASP. This means that effective stewardship serves as a protective factor against the escalation of antimicrobial resistance.

Further qualitative analysis shows that the success of ASP is highly dependent on the support of the hospital's top management. Respondents from hospitals with the support of active directors and department heads reported better coordination between departments, dedicated time allocation for ASP meetings, and funding for training activities. In contrast, in hospitals that consider ASP as an additional program without internal policy support, the sustainability of activities often stalls due to the absence of incentives and time priority for medical personnel.

Organizational culture factors also play a big role in the effectiveness of ASP. In some hospitals, a strong clinical hierarchy leads to junior doctors being reluctant to refuse or correct antibiotic prescriptions from senior doctors, even if it is against guidelines. In this context, interdisciplinary training and a non-punitive approach to antibiotic audits are crucial for behavior change to be achieved sustainably. Without cultural change, ASP policies risk becoming mere administrative formalities with no real impact on clinical practice.

Other limitations identified are high workload and lack of competent human resources in the analysis of antibiotic use data. Many hospitals still rely on manual record-keeping, so evaluating compliance with protocols is time-consuming and error-prone. The implementation of digital systems such as WHONET and integrated reporting platforms has been proven to accelerate the detection of antibiotic use patterns and resistance, but only a small percentage of facilities have such infrastructure.

Overall, these results confirm that the success of the *Antibiotic Stewardship Program* depends on a combination of institutional support, the availability of trained human resources, an efficient data system, and the organization's cultural commitment to upholding rational practices for antibiotic use. Policy implementation without strong monitoring and evaluation mechanisms will not have a significant impact on antimicrobial resistance. Therefore, national resistance control efforts in the Philippines should be focused on strengthening the capacity of regional hospitals so that the implementation of ASP is not only symbolic, but truly serves as an evidence-based resistance control instrument.

3.4. Comparative Discussion and Global Context

The findings of this study reinforce the results *of Scientific Reports* (2024) and *The Lancet Microbe* (2024), which show a global increase in resistance to key antibiotics in the wake of the COVID-19 pandemic. This surge not only reflects the impact of overuse of antibiotics during the pandemic, but also indicates the weakness of resistance surveillance systems in various developing countries. In the Philippines, the trend of significant increases in resistance to ciprofloxacin, ceftriaxone, and oxacillin suggests that these global patterns have direct relevance to the national context. This similarity

confirms that the resistance crisis is a cross-border phenomenon that requires policy coordination between countries in the ASEAN region.

The pattern of increased resistance in the Philippines is very similar to that reported in Malaysia and Thailand, where extensive empirical antibiotic administration practices during the pandemic were a major factor. Another factor that has contributed to the worsening of the situation is limited access to rapid diagnostics and antibiotic sensitivity tests in primary care facilities. As a result, many cases of viral infections remain treated using broad-spectrum antibiotics, strengthening the pressure of selection against resistant bacteria. These dynamics suggest that resistance is not only a microbiological problem, but also a health system problem and clinical behavior that requires multidimensional interventions.

Nevertheless, the effective implementation of *the Antibiotic Stewardship Program* (ASP) has been shown to have a significant protective effect on increased resistance. Hospitals that implemented a laboratory-based antibiotic audit system reported a decrease in resistance of up to 12% in two years, compared to hospitals without a structured surveillance system. Audit mechanisms that link culture outcomes and antibiotic sensitivity to prescribing patterns have been shown to encourage more rational clinical behavior change. In other words, laboratory data serves as the primary control tool in directing appropriate antibiotic use practices.

The success of laboratory-based ASPs is also influenced by how often and how transparent audit results are shared with the physician in charge of the patient. Hospitals that have regular forums to discuss resistance trends and feedback from audit results show higher adherence to clinical guidelines. In addition, periodic training for physicians and pharmacists strengthens their ability to interpret resistance data, making therapeutic decision-making more evidence-based. This shows that the effectiveness of ASP depends not only on the existence of the system, but also on the active involvement of health workers at all levels.

Thus, the results of this study confirm the importance of the transformation of ASP in the Philippines from an administrative approach to a data-driven system and continuous learning. This kind of approach not only suppresses resistance in the short term, but also strengthens the capacity of hospitals to detect, analyze, and respond to resistance patterns that change over time. When supported by national policies that encourage the digitization of resistance data and collaboration between hospitals, a strong ASP system can be a key foundation in dealing with the threat of antimicrobial resistance at the national and regional levels.

3.5. Policy and Public Health Implications

These findings have strong strategic implications for the direction of national health policy in the Philippines, particularly in the context of antimicrobial resistance control in the post-COVID-19 pandemic. The increase in resistance to first-line antibiotics in E. coli and S. aureus suggests that existing infection control policies are not effective enough in preventing the spread of resistant strains. This situation demands a systemic transformation that includes data integration, laboratory capacity building, and reform of antibiotic use governance at the health institution level.

First, the integration of data from *the Antimicrobial Resistance Surveillance Program* (ARSP) with hospital information systems is a fundamental step. By connecting resistance data in *real-time*, hospitals can tailor empirical therapy guidelines based on actual trends in resistance in their respective facilities. This approach allows for more adaptive and evidence-based internal antibiotic policies, while accelerating responses to new patterns of resistance. In the era of health digitalization, data interoperability between ARSP systems and electronic medical records will be the main foundation in effective antibiotic policy planning.

Second, increasing the capacity of human resources is an important element in strengthening *the Antibiotic Stewardship Program* (ASP). Continuing education for clinicians, nurses, and clinical pharmacists needs to focus on the principles of rationality for the use of antibiotics, the interpretation of microbiological data, and the importance of waiting for culture results before administering therapy. This kind of training has been shown to improve adherence to therapeutic guidelines and significantly decrease the use of broad-spectrum antibiotics. Without consistent educational efforts, even the best ASP policies will not run optimally at the clinical level.

Third, strengthening the capacity of microbiology laboratories, especially in regional hospitals, is a prerequisite for the successful implementation of the national ASP. Many hospitals in the Visayas and Mindanao regions still rely on reference facilities in Manila for resistance testing, leading to delays in diagnosis and reliance on empirical therapies. Government investment in automated culture

equipment, diffusion disk-based sensitivity tests, and analyst training is critical to faster and more accurate resistance detection across regions.

In addition, strengthening the *audit-feedback mechanism* in each hospital needs to be made a national standard. Through regular antibiotic use audits, the ASP team can provide corrective recommendations to physician prescribing patterns and encourage ongoing clinical behavior change. Evidence from this study shows that hospitals with active audit systems experience a slower increase in resistance than hospitals without audits. Therefore, national policies need to require at least quarterly antibiotic audits in all government health facilities.

Another crucial aspect is policy support and funding from the Philippine Ministry of Health. Without budget support for training, laboratory equipment, and resistance data digitization systems, national ASP policies will be difficult to implement consistently. The government needs to ensure that each hospital has a functional ASP team with clear roles and responsibilities, as well as provide incentives for facilities that demonstrate success in lowering resistance levels. This kind of political and administrative support is a key catalyst for the long-term sustainability of the program.

Overall, the results of this study support the hypothesis that E. coli and S. aureus resistance increased significantly post-pandemic due to uncontrolled use of antibiotics. Furthermore, these results affirm the urgency of implementing *the Antibiotic Stewardship Program* in a comprehensive, integrated, and sustainable manner throughout the Philippine health system. By combining data-driven approaches, strengthening laboratories, training of medical personnel, and adaptive policies, the Philippines can slow the rate of resistance and strengthen the resilience of its health system to future antimicrobial threats.

4. Conclusion

The study confirms that antimicrobial resistance (AMR) to first-line antibiotics increased significantly in Philippine government hospitals after the COVID-19 pandemic. Analysis of WHONET data showed a surge in *E. coli* resistance to ciprofloxacin and ceftriaxone, as well as an increase *in the proportion of oxacillin-resistant Staphylococcus aureus* (MRSA). A statistically significant relationship ($p < 0.001$) between the pandemic period and increased resistance supports the hypothesis that the widespread use of empirical antibiotics during the pandemic contributed significantly to the acceleration of resistant strain selection. COVID-19, thus, is not only a viral infection crisis, but also a catalyst for an increase in AMR in healthcare facilities.

In addition, the results of interviews with infectious doctors and *the Antibiotic Stewardship Program* (ASP) team confirmed that the effectiveness of resistance control is highly dependent on the consistency of ASP policy implementation and supporting infrastructure support. Hospitals with regular audit-feedback systems and management support showed a smaller increase in resistance than facilities without active ASPs. Limited microbiology laboratory capacity and lack of *real-time* integration of resistance data remain major obstacles in evidence-based decision-making. Overall, strengthening ASP, increasing laboratory capacity, and integrating resistance information systems are strategic steps to slow the pace of AMR increase and strengthen the resilience of the national health system.

Some of the recommendations from this research include:

1) Strengthening National ASPs: Require the establishment of multidisciplinary Antibiotic Stewardship Program (ASP) teams in all government hospitals to ensure antibiotic audits and reporting are consistent.
2) Resistance Data Integration: Connect the Antimicrobial Resistance Surveillance Program (ARSP) system with the hospital's information system so that resistance monitoring can be performed in real-time and used for evidence-based therapy policies.
3) Public Education: Increase national campaigns on the dangers of antibiotic abuse through cross-sectoral collaboration with health, education, and media agencies.
4) Laboratory Capacity Building: Prioritize strengthening microbiology laboratories in area hospitals, including the provision of modern culture equipment, automated sensitivity tests, and expert training.
5) Monitoring and Evaluation: Conduct regular evaluations of the effectiveness of ASP implementation and resistance levels in each hospital to ensure the sustainability of AMR control policies.

Further research needs to be expanded to include private hospitals and primary health facilities to obtain a comprehensive national picture of antimicrobial resistance trends in the Philippines. Cross-regional and socioeconomic studies are also needed to understand the determinants of resistance variation. In addition, genomic approaches such as *whole-genome sequencing* (WGS) are important to be developed to map the spread of resistance genes and horizontal transfer mechanisms between bacterial species. Long-term intervention research evaluating the effectiveness of digital-based *Antibiotic Stewardship Program* (ASP) models, including automated audit systems and antibiotic prescription reminders, is expected to be the basis for the development of a national strategy for sustainable and adaptive resistance control to technological advances.

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