

Strengthening Indonesia's Emerging Infectious Disease Surveillance to Care Ecosystem: A Mixed-Methods Study of Challenges and Facilitators

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Abstract

Background

Effective surveillance systems are critical for early detection of emerging infectious diseases (EIDs). Challenges and facilitators can impact surveillance performance at the individual, social, policy, and community levels. This study aimed to identify barriers and enablers to strengthen the surveillance ecosystem across these levels.

Methods

A mixed-methods study was conducted across 21 public health centers in Bali, Indonesia. Quantitative analysis was conducted using mixed-effects linear regression on data from 349 participants to examine factors associated with the surveillance score. Qualitative data from 18 in-depth interviews and 20 focus group discussions, involving 38 participants, were thematically analyzed to explore barriers and facilitators to surveillance implementation.

Results

In the adjusted model, knowledge of surveillance was significantly associated with surveillance score ($\beta = -0.328$; 95% CI: -0.589 to -0.067 ; $p = 0.014$). Facility readiness, community engagement, and interaction terms were not statistically significant. Qualitative findings identified key barriers, including limited human resources, fragmented reporting systems, logistical constraints, reagent shortages, weak coordination, and misinformation within communities. Bureaucratic procurement processes and inadequate digital infrastructure further delayed reporting and specimen transport. Facilitators included rapid response teams, digital reporting systems, routine cross-sector meetings, training for staff, and active involvement of community leaders and health cadres.

Conclusions

Surveillance performance is influenced by both individual knowledge and systemic health system factors. Strengthening referral coordination, workforce capacity, digital integration, and community engagement is essential to enhance EID surveillance effectiveness.

Introduction

A lustrums passed, emerging infectious diseases (EIDs) continue to pose a significant threat to global health security due to their unpredictability, rapid transmission dynamics, and complex socioecological factors (Wegner et al., 2022; De Gaetano et al., 2025; Nova et al., 2022). In low- and middle-income countries (LMICs), surveillance capacity is frequently hampered by fragmented information systems,

inadequate laboratory infrastructure, and a lack of trained personnel (Matshine et al., 2025; Harapan et al., 2023; Kabajaasi et al., 2025; Meierkord et al., 2024). These limitations exacerbate the gap between early detection and timely intervention, hindering outbreak control and escalating the risk of sustained community transmission.

Global analyses indicate that the timeliness of outbreak discovery and public communication has improved by approximately 6–7% annually supporting by decent surveillance and reporting frameworks (Koopmans., 2013; Chan et al., 2010). Enhancing surveillance systems involves more than simply implementing technological upgrades or enacting policy reforms; it requires a thorough understanding of the broader ecosystem in which surveillance functions (Vološevici & Isbasoiu., 2025). The socio-ecological model (SEM) serves as a valuable framework for examining how health system performance is influenced by interconnected determinants across various levels, including individual, interpersonal, organizational, community, and policy contexts (Kilanowski., 2017). Applying this framework to EID surveillance enables a more comprehensive examination of both structural barriers and enabling factors influencing detection and response.

At the individual level, frontline health workers play a pivotal role in recognizing suspected cases, initiating reporting procedures, and coordinating referrals (Alhassan & Wills., 2024; Ngayah et al., 2023). Their knowledge of emerging pathogens, familiarity with reporting platforms, risk perception, and competing clinical responsibilities directly influence surveillance timeliness and completeness. In many LMIC settings, including Indonesia, inadequate training on evolving case definitions, limited access to diagnostic tools, and high workload burden can delay notification and compromise data quality (Harapan et al., 2023; Erica et al., 2025; Wasir et al., 2024; Mashuri et al., 2024; Sinuraya et al., 2026). Conversely, good knowledge attitude and practice, continuous professional development, and supportive supervision may serve as key facilitators of effective surveillance (Phalkey et al., 2015; Shorbaji et al., 2026).

At the interpersonal and organizational levels, relationships and coordination mechanisms among health facilities, laboratories, and district health offices determine how efficiently information flows across the system (Harapan et al., 2023; Sinuraya et al., 2026; Dama et al., 2024; Owusu et al., 2025; Njukeng et al., 2022; Dowdy, 2017). Indonesia's decentralized governance structure grants significant autonomy to subnational authorities, which may result in variations in reporting practices and resource allocation (Sinuraya et al., 2026; Harapan et al., 2023). Fragmented communication channels, overlapping reporting requirements, and delayed laboratory confirmation represent recurring operational challenges. However, strong leadership, clear feedback loops, and functional referral systems can enhance coordination and responsiveness (Dama et al., 2024; Owusu et al., 2025; Dowdy, 2017; Nkrumah et al., 2025; Njukeng et al., 2022; Matshine et al., 2025; Mashuri et al., 2024).

Community and broader social determinants further influence surveillance performance. Indonesia's status as the world's largest archipelagic nation creates geographic barriers to timely reporting and specimen transport (Harapan et al., 2023; Sinuraya et al., 2026). Unequal distribution of digital infrastructure and health resources contributes to disparities in data integration and access to

diagnostic services (Cuadros et al., 2025; Wasir et al., 2024; Hadijat, 2023). In addition, socioeconomic inequalities, health literacy levels, and trust in public health authorities affect care-seeking behavior and community engagement in surveillance activities (Owoyemi et al., 2021; Nugrahani et al., 2023; Cuadros et al., 2025; Wasir et al., 2024). Community-based engagement strengthened surveillance and response by enabling local teams and traditional networks to actively track, identify, and report symptomatic individuals, particularly in high-density areas, while local leaders enhanced trust, improved risk communication, and countered misinformation in a post-truth environment. Moreover, community involvement reduced stigma toward positive individuals and provided practical support for self-isolation, such as distributing food and hygiene supplies, thereby increasing compliance with testing, reporting, and quarantine measures (Pascawati et al., 2022).

At the policy level, Indonesia has introduced national reforms aimed at strengthening health information systems (Agustina et al., 2019), including the SatuSehat integrated digital health platform and alignment with the International Health Regulations (IHR 2005) (Utomo et al., 2025). While these initiatives signal political commitment to health security, implementation EID surveillance gaps persist at the frontline levels such as limited toolkits, and workload burdens (Harapan et al., 2023)

Taken together, there is a critical evidence gap regarding the multilevel challenges and facilitators influencing the strengthening of Indonesia's emerging infectious disease surveillance-to-care ecosystem. Few studies have adopted a socio-ecological perspective to explore how individual competencies, organizational processes, community determinants, and policy environments interact to shape surveillance performance. This study aims to address this gap by examining the challenges and facilitators of strengthening the EID surveillance ecosystem in Indonesia using a mixed-methods approach.

Methods

The mixed-methods approach was chosen to enable both statistical assessment of patterns across health facilities and an in-depth understanding of contextual factors influencing surveillance implementation, in line with the Mixed Methods Appraisal Tool (MMAT, 2018) framework (Hong et al., 2018).

Quantitative Study

The study was conducted in two districts of Bali, Indonesia namely Denpasar and Jembrana to encompass proximity from tertiary hospital and national laboratory, aimed to evaluate the potential geographic and administrative disparities. This study involved a total of 21 primary health centers (Puskesmas) (11 in Denpasar and 10 in Jembrana). Data collected between July and August 2025. A stratified random sampling technique was applied, using health professionals as the stratification criterion. Based on the Slovin formula with a 5% margin of error and an assumption that 80% of health

workers were employed in primary care, the minimum sample size was estimated at 295 participants (Slovin, 1960). Accounting for a 10% non-response rate, the final target sample was 325 participants.

To evaluate the challenges and facilitators of the participant, we developed a questionnaire aligned with the Socio Ecological Model (SEM) Framework by Urie Bronfenbrenner (Kilanowski, 2017). The questionnaire consists of 1) perception and knowledge and attitudes in integrating EIDs surveillance, and 2) surveillance performance and 3) barriers and facilitators in strengthening EIDs surveillance as captured in Supplementary Table 1. The instrument underwent content validation using the Content Validity Index (CVI) with input from multidisciplinary health professionals possessing clinical and academic expertise. Construct validity was then tested through online administration to 30 health professionals representing diverse cadres (physicians, nurses, midwives, pharmacists, laboratory analysts, and academicians). Data from this stage were analyzed using Exploratory Factor Analysis (EFA) and Cronbach's alpha to evaluate internal consistency. The overall questionnaire has good reliability of 0.96.

In practice, 349 valid responses were included in the analysis, following inclusion criteria of: active healthcare workers (medical doctors, dentists, nurses, midwives, pharmacists, laboratory analysts, public health and environmental health officers, nutritionists, dental therapists, and surveillance officers) who were healthy and willing to participate. The administrative staff, interns, and individuals on medical or personal leave were excluded.

Descriptive statistics (means, standard deviations, frequencies, and percentages) were used to summarize demographic characteristics and responses. Mixed Linear Model Regression was employed to analyze the challenges and facilitators of strengthening EID surveillance in the individual and social determinants levels. We analyzed the individual determinants then grouped them into their healthcare facilities to evaluate the organizational determinants level. All analyses were performed using R version 4.4.3.

Qualitative Study

In the meantime, through the purposive sampling technique, we invited 18 healthcare professionals to do online in-depth interviews (IDIs). Interviews explored: 1) local challenges in EID surveillance implementation, 2) effective facilitating factors, 3) perspectives on integrating Puskesmas into surveillance and care systems. Focus Group Discussions (FGDs) were organized in community settings to capture perspectives from both healthcare workers and community representatives. Each group consisted of 10 participants, including nine health professionals (doctor, nurse, midwife, surveillance officer, disease control program holder, pharmacist, laboratory analyst, environmental health officer, and nutritionist/manager) and one community leader (head of neighborhood).

Participants were purposively selected to ensure diverse representation across urban and rural settings. All IDIs and FGDs were audio-recorded with participant consent and transcribed verbatim. Thematic

analysis was conducted using NVivo 12, involving data familiarization, coding, categorization, and theme identification.

Triangulation

A convergent parallel mixed-methods design was applied, allowing quantitative and qualitative data to be collected and analyzed independently before integration. Triangulation was conducted by comparing quantitative trends with qualitative insights to enhance interpretation validity and generate meta-inferences. Divergences between data types were systematically analyzed to identify contextual nuances or explanatory factors.

Ethics

Ethical clearance was obtained from the Research Ethics Committee, Faculty of Medicine, Universitas Udayana (Approval No. 1818/UN14.2.2.VII.14/LT/2025). All participants provided informed consent prior to participation. Confidentiality and anonymity were maintained throughout the study.

Results

The study evaluates the challenges and facilitators in strengthening surveillance EID in Indonesia experienced by healthcare professionals. Furthermore, the individual and social determinants were explored. Table 1 describes the participant characteristics. Of 349 respondents, 85.7% were female, 49.9% graduated from a bachelor's degree, including a professional degree, worked for 9.9 years on average, and were permanent workers (96.6%). Of 21 public health centers, the majority worked at Puskesmas 1 Melaya. Midwives (34.1%) followed by doctors (11.7) were the most professional in this study.

Table 1
Characteristics of the participants

Characteristics	n	(%)
N	349	100
Sex		
Male	50	14.3
Female	299	85.7
Age (years) (Mean $\pm$ SD)	38 $\pm$ 8.5	
Education		
Diploma	161	46.1
Bachelor and Profession	174	49.9
Postgraduate	14	4.0
Length of service (years) (Mean $\pm$ SD)	9.9 $\pm$ 7.5	
Employment status		
Permanent	337	96.6
Contract	12	3.4
Geographic area		
Denpasar City	183	52.5
Jembrana District	166	47.5
Healthcare unit		
Puskesmas 1 Denpasar Barat	6	1.7
Puskesmas 2 Denpasar Barat	16	4.5
Puskesmas 1 Denpasar Selatan	20	5.7
Puskesmas 2 Denpasar Selatan	19	5.4
Puskesmas 3 Denpasar Selatan	18	5.1
Puskesmas 4 Denpasar Selatan	13	3.7
Puskesmas 1 Denpasar Timur	16	4.5
Puskesmas 2 Denpasar Timur	18	5.1
Puskesmas 1 Denpasar Utara	22	6.3
Puskesmas 2 Denpasar Utara	7	2.0

Characteristics	n	(%)
Puskesmas 3 Denpasar Utara	28	8.0
Puskesmas 1 Negara	22	6.3
Puskesmas 2 Negara	18	5.1
Puskesmas 1 Melaya	37	10.6
Puskesmas 2 Melaya	8	2.2
Puskesmas 1 Mendoyo	22	8.0
Puskesmas 2 Mendoyo	14	4.0
Puskesmas 1 Pekutatan	5	1.4
Puskesmas 2 Pekutatan	20	5.7
Puskesmas 1 Jembrana	5	1.4
Puskesmas 2 Jembrana	15	4.2
Profession		
Doctor	41	11.7
Dental hygienist	16	4.6
Nurse	79	22.6
Midwife	119	34.1
Laboratory technician	14	4.0
Pharmacies	19	5.4
Surveillance officer	6	1.7
Sanitary officers	17	4.9
Nutritionist	14	4.0
Dental therapist	10	28.6
Management officers	13	3.72

Tabel 2 described factor in strengthening surveillance at organizational level, surveillance performance demonstrated the highest mean score (4.04 ± 0.41), indicating consistently strong implementation practices across facilities. Indicators of structural readiness, including established referral systems (3.91 ± 0.64), healthcare facility readiness (3.76 ± 0.69), availability of trained staff (3.67 ± 0.78), and availability of diagnostic tools and kits (3.43 ± 0.74), showed generally favorable perceptions, although variability was observed in workforce and diagnostic capacity. In contrast, community engagement

yielded the lowest mean score (2.26 ± 0.75), suggesting that external coordination and partnership mechanisms remain comparatively underdeveloped despite adequate internal organizational preparedness.

Table 2
Factors in strengthening EIDs surveillance in Indonesia

Variabel	Mean $\pm$ Standard Deviation
Knowledge of Surveillance	3.19 ± 0.77
Surveillance Performance	4.04 ± 0.41
Availability of trained staff	3.67 ± 0.78
Availability of diagnostic tools and kits	3.43 ± 0.74
Established referral	3.91 ± 0.64
Healthcare Facilities readiness	3.76 ± 0.69
Community engagement	2.26 ± 0.75

Barriers and Facilitators Associated with Surveillance

Knowledge of surveillance were significantly associated with surveillance performance. Knowledge of surveillance was positively associated with surveillance score ($\beta = 0.054$; 95% CI: 0.012 to 0.097; $p = 0.01$), indicating higher surveillance performance among respondents with greater surveillance knowledge. Furthermore, among system-level factors, established referral mechanisms were significantly associated with higher surveillance scores ($\beta = 0.117$; 95% CI: 0.059 to 0.176; $p = 0.01$). Availability of trained staff showed a positive but non-significant association ($\beta = 0.061$; 95% CI: -0.003 to 0.125; $p = 0.06$), while availability of diagnostic tools and kits was not significantly associated with surveillance score ($\beta = 0.040$; 95% CI: -0.019 to 0.098; $p = 0.18$).

Table 3
Associated Factors to Barriers and Facilitators in Strengthening Attitudes and Experiences in Integrating Surveillance Care from an Individual Level-Perspective

Variable	Coefficient (β)	95% Confident Interval (CI)		<i>p-value</i>
		<i>Lower</i>	<i>Upper</i>	
Knowledge of Surveillance	0.054	<i>0.012</i>	<i>0.097</i>	0.01*
Availability of trained staff	0.061	<i>-0.003</i>	<i>0.125</i>	<i>0.06</i>
Availability of diagnostic tools and kit	0.040	<i>-0.019</i>	<i>0.098</i>	<i>0.18</i>
Established referral	0.117	<i>0.059</i>	<i>0.176</i>	0.01*
Age	0.004	-0.001	0.01	0.09
Years of service	-0.000	-0.006	0.006	0.94

Sociodemographic and professional characteristics were not significantly associated with surveillance performance. Age showed a small positive association with surveillance score; however, this association did not reach statistical significance ($\beta = 0.004$; 95% CI: -0.001 to 0.010; $p = 0.09$). Years of service were not associated with surveillance score ($\beta = -0.000$; 95% CI: -0.006 to 0.006; $p = 0.94$), indicating that duration of professional experience did not influence surveillance outcomes.

Health Facility and Community Involvement in Strengthening Surveillance

In the mixed-effects linear regression model, knowledge score was the only variable significantly associated with surveillance score ($\beta = -0.328$; 95% CI: -0.589 to -0.067; $p = 0.014$). The negative coefficient indicates that higher knowledge scores were associated with lower surveillance scores. This association remained statistically significant after accounting for clustering across 21 public health centers.

System-level variables were not independently associated with surveillance score. Facility score showed no significant association with surveillance performance ($\beta = -0.025$; 95% CI: -0.225 to 0.176; $p = 0.810$). Similarly, community score was not significantly associated with surveillance score ($\beta = -0.031$; 95% CI: -0.215 to 0.153; $p = 0.743$). These findings suggest that, within this model, facility readiness and community engagement did not independently explain variation in surveillance outcomes.

Table 4

Association Factors to Barriers and Facilitators in Strengthening Attitudes and Experiences in Integrating Surveillance Care in Organizational Level

Variable	Coefficient (β)	95% Confident Interval (CI)		<i>p-value</i>
		<i>Lower</i>	<i>Upper</i>	
Knowledge of surveillance	-0.32	-0.58	-0.06	0.01*
Healthcare Facilities Readiness	-0.02	-0.22	0.17	0.81
Knowledge × Healthcare Facilities readiness	0.05	-0.009	0.12	0.09
Community Engagement	-0.03	-0.21	0.15	0.74
Knowledge × Community Engagement	0.04	-0.01	0.10	0.16

Interaction effects between knowledge and healthcare facilities factors did not reach statistical significance. The interaction between knowledge score and facility score demonstrated a positive but marginal association ($\beta = 0.058$; 95% CI: -0.009 to 0.126; $p = 0.092$), whereas the interaction between knowledge score and community score was not statistically significant ($\beta = 0.044$; 95% CI: -0.017 to 0.106; $p = 0.160$). The between-group variance was small (Group Var = 0.001), indicating that most of the variability in surveillance score occurred at the individual level rather than at the group level.

Qualitative Findings

We conducted interviews with 38 healthcare workers, 18 healthcare workers through in-depth interviews, and 20 healthcare workers by focus group discussion from 21 healthcare centers (refer to online supplemental table). The interviews uncovered a variety of barriers and facilitators to strengthening emerging infectious disease surveillance.

Aligning with quantitative finding, knowledge of surveillance and established referral significantly influence surveillance on an individual level. Through deep exploration of the individual knowledge of surveillance influenced by human resource constraints and data management. Further, behind established referral pathway procurement delay and limited health facilities as well as logistic remain the the problem. Meanwhile, at organizational level the knowledge of surveillance persists influencing surveillance, means limited human resources, poor coordination and data management and complicated bureaucracy slower the surveillance reporting process.

Barriers to Surveillance Implementation

In Indonesia, post-pandemic recovery has led to investments in digital health infrastructure and workforce training. Nevertheless, disparities in human resources, coordination and data management,

complicated bureaucracy and limited external support interoperability persist in individual level. The risk is not that identical failures will recur, but that unresolved systemic fragilities may manifest differently under future crisis conditions. This study moves beyond retrospective previous pandemic analysis and evaluates the present readiness landscape to inform proactive pandemic preparedness strategies.

Human resource constraints were consistently reported as a major challenge. Healthcare workers described shortages of trained personnel, increased workload, and multitasking across programs, particularly during the pandemic. Participants highlighted workforce limitations:

"One person can have 3 to 5 jobs. Then there are emergencies, and we run out of human resources." -

Health Promotion, Denut 2

"There is a severe shortage, especially of swebers. Previously during COVID-19, there was only one community health center and only one trained person, but there are many targets." – **Nurse, Mendofo 1**

Healthcare facility and logistics limitations further constrained surveillance implementation, possibly to disrupt the referral pathway. Participants described inadequate personal protective equipment (PPE), reagent shortages, limited digital infrastructure, unstable internet access, and lengthy procurement procedures.

"In the beginning, because we didn't really understand, we wanted to use standard PPE. When treating patients, before we had PPE, we used raincoats." - **Principal of PHC Denbar 1**

Testing capacity was also restricted in both city:

"Reagent shortages, human resource limitations. So that might be what's limiting COVID testing." –

Nurse Dentim 2

Procurement delays were attributed to bureaucratic processes, limit the knowledge of surveillance at an organizational level:

"The procurement regulations are lengthy, followed by approval, then implementation, and finally purchase." - **Health Promotion Officer Denut 2**

"Policies should not be overly idealistic; they should be tailored to the conditions in the community." -

Mendofo 1 Nurse

Digital infrastructure constraints were observed both in individual and organizational level, lowering the knowledge of surveillance and referral pathway, its emphasized:

"Sometimes there are data inconsistencies, and every day we have to keep validating them." -

Surveillance Officer Densel 4

"There are many systems, we have to input data into too many applications that are not merged, so sometimes we feel overwhelmed." - FGD Jembrana (Health Workers).

Facilitators Strengthening Surveillance

Despite these barriers, several enabling factors were identified. Strengthening human resources, facilitating training to healthcare workers, improving digital infrastructure, enhancing community engagements and obtaining external support during the crisis was viewed as critical, regardless the geographical constraint in Indonesia.

Investing in human resources through rapid preparation training is essential:

"If there are changes in emergency preparedness guidelines, we will definitely be trained." - **Infectious Disease Program Officers Jembrana**

"Training about sampling, shipping samples, and packaging samples in the field." - **Health Analyst Denut 1**

For future pandemic preparedness, strengthening logistics across public health centers is crucial:

"We need to ensure sufficient availability of reagents, vaccines, and PPE, with faster and more flexible procurement mechanisms, especially during outbreaks." – **Jembrana FGD**

Digital infrastructure and real-time reporting systems were described as facilitating coordination:

"Our team at the community health center was also able to access the reports in real time at that time, so our coordination became much easier." – **Surveillance Officer Densel 4**

"As for our system at the community health center, everything is digital. So, everything we do is reported through the system." - **Midwife Densel 2**

Regular coordination meetings is beneficial to transfer knowledge from public health centers to community how to prevent the spreads of diseases and communication platforms further supported implementation:

"There is a monthly activity called the monthly mini workshop..." - **Principal of PHC Denbar 1**

"Every month there is a cross-program meeting where we convey information to our colleagues." - **Nurse Mendoyo 1**

External support from foundations supplemented limited resources:

"Many foundations assisted us at the health center in the form of PPE such as masks, gloves, and hand sanitizer." – **Principle of PHC Mendoyo 1.**

Discussion

Our study aimed to evaluate the barriers and facilitators in individual, social determinants and community level to strengthening emerging infectious disease surveillance ecosystem. The results highlight three findings 1) good knowledge of topic-related infectious emerging diseases associated with attitude and practice towards surveillance, 2) established referral flow associated with attitude and practice towards surveillance 3) knowledge proficiency in emerging infectious disease surveillance aligns with the lower score of attitude and practice towards surveillance. Quantitative barriers in individual and organizational level such as lack of human resources, poor coordination, data management, procurement delay, limited healthcare facilities and logistic challenges the improvement of EIDs surveillance. In order to strengthen the EIDs surveillance, improvement in human resources, rapid response training, robust data management system, regular coordination meetings and external support were needed.

First, proficient insight of topic-related infectious emerging diseases contributes to lower IHR scores, aligning with previous findings shows that countries that excel in surveillance often utilize frameworks such as the Global Health Security (GHS) Index (Bel et al., 2019; Nuzzo, 2021). Higher scores in detection and reporting are associated with better outcomes in controlling outbreaks, as low IHR scores increase the risk of inadequate management by 3 to 11 times (Tsai & Tipayamongkhogul., 2020). Effective surveillance delivers critical data on outbreaks, including influenza D and canine coronaviruses, thereby enhancing the global response (Gray et al., 2026).

Second, a quick and effective response to emerging infectious diseases linked with a well-defined referral process, as our study highlights. We found that a standardized referral protocol is associated with the highest EID surveillance scores. Referral systems streamline the processes of sample collection, packaging, transportation, tracking, and returning results, significantly reducing turnaround times from weeks to just days (Owusu et al., 2025; Shen et al., 2025). This continuity helps prevent the formation of data silos, allowing for near real-time outbreak confirmation, which is essential in addressing emerging threats where delays can exacerbate the spread of disease (Owusu et al., 2025; Shen et al., 2025). In the Global Health Security (GHS) Index, indicators related to specimen referral and transport, such as those reflecting nationwide systems (Bel et al., 2019; Nuzzo et al., 2021).

Last, we found that higher knowledge scores are associated with lower surveillance scores among healthcare workers in 21 public health centers. In fact, higher individual knowledge does not necessarily translate into improved implementation within existing structural constraints. In our study setting, surveillance activities are influenced by system-level factors such as reporting workload, administrative burden, insufficient technological advancements, and coordination challenges, logistic still remain concern through qualitative findings.

The existence of 38 provinces, over 500 districts, and more than 80,000 villages, coupled with partial fiscal decentralization, has made it challenging to standardize coordinated pandemic policies and referrals across the islands (Harapan et al., 2023). Differences in local governance capacity have

resulted in varied implementation of testing, tracing, and movement restrictions, further complicating national efforts to control emerging infectious diseases (EIDs) (Sinuraya et al., 2026; Harapan et al., 2023). The lack of established referral systems can significantly undermine surveillance effectiveness due to various structural and operational constraints. The fragmented and vertical nature of referral pathways across different disease programs (such as TB, HIV, polio, and COVID-19) leads to redundancy, inconsistent standards, and gaps in coverage for EIDs, particularly in the absence of a unified national coordination mechanism (Dowdy, 2017; Meierkord et al., 2024; Mashuri et al., 2024; Nkrumah et al., 2025).

Additionally, logistical and infrastructural challenges including insufficient transportation, inadequate cold chain capacity, and chronic underfunding result in delayed turnaround times, missed or rejected specimens, and reduced geographic coverage, particularly in remote areas where EIDs frequently arise (Dowdy, 2017; Ntingiya et al., 2021; Nkrumah et al., 2025; Owusu et al., 2025; Kabajaasi et al., 2025). The absence of standardized operating procedures, biosafety guidelines, and adequately trained personnel further jeopardizes the safe packaging, transportation, and documentation of specimens (Zimolzak et al., 2022; Nkrumah et al., 2025). Furthermore, weak communication systems, limited tracking mechanisms, and poor integration between transportation, laboratory, and surveillance databases hinder real-time monitoring and performance evaluation (Judith et al., 2018; Njukeng et al., 2022; Dama et al 2024). Collectively, these systemic weaknesses may diminish the efficiency, timeliness, and completeness of reporting processes, ultimately impacting overall surveillance scores negatively.

Conclusion

This study demonstrates that surveillance knowledge and established referral pathways significantly influence surveillance performance at both individual and organizational levels. At the individual level, performance is constrained by limited human resources, high workload, and weaknesses in data management systems, while procurement delays, logistical barriers, and limited facility capacity undermine effective referral implementation. At the organizational level, although surveillance knowledge remains a key determinant, its impact is hindered by poor coordination, bureaucratic complexity, and limited data interoperability, which slow reporting processes and reduce responsiveness. Despite post-pandemic investments in digital health infrastructure and workforce training in Indonesia following the COVID-19 pandemic, persistent systemic fragilities continue to threaten preparedness for future crises. This study's strengths lie in its multilevel analytical approach and integration of quantitative and qualitative findings, offering policy-relevant insights for health system strengthening; however, its cross-sectional design, reliance on self-reported measures, and context-specific setting may limit causal inference and broader generalizability.

Declarations

Conflict of Interest

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