Modeling the Potential Spread of Middle East Respiratory Syndrome Coronavirus (MERS-CoV) and Evaluating Strategic Preparedness Measures in Thailand

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Abstract

Middle East respiratory syndrome (MERS) remains a public health threat due to its severity and potential for nosocomial and international transmission. Thailand remains at risk of a MERS outbreak due to ongoing travel, pilgrimage, and trade with the Middle East, despite having no confirmed case since 2016. This study aimed to assess the potential spread of MERS-CoV and evaluate national preparedness for MERS outbreaks by using a mixed-methods study. A quantitative study employed Susceptible-Exposed-Infectious-Recovered models to simulate the dynamics of MERS outbreaks under various scenarios in Yala, Pattani, and Narathiwat provinces. The qualitative component included documentary reviews and in-depth interviews with 21 key policymakers, experts, and relevant officers from provincial, sub-national, national, and international levels. The modeling revealed a low likelihood of widespread outbreaks, and combined interventions and early detection resulted in decreased peak and cumulative outcomes across various basic reproductive number values. Documentary reviews revealed that in Thailand, MERS surveillance was integrated into the national communicable disease surveillance, and its priority has diminished since 2016. In-depth interviews showed strengths in strategic plans, human resources, and cross-sector coordination, although gaps were identified in MERS-specific surveillance systems, laboratory surge capacity, insufficient community-level preparedness, and fragmented data systems. The results showed that Thailand has foundational capacity for MERS, supported by enhanced public health infrastructure following the COVID-19 pandemic. Recommendations include strengthening combined intervention and early detection measures, MERS-specific surveillance protocols, laboratory capacities, health literacy among high-risk groups such as pilgrims and caregivers, preparing sufficient resources, and enhancing digital health systems.

Keywords: spreading, preparedness, Middle East respiratory syndrome, MERS, MERS-CoV, Thailand, SEIR modeling

Introduction

Middle East respiratory syndrome (MERS), caused by the Middle East respiratory syndrome coronavirus (MERS-CoV), has been reported in 2,627 confirmed cases and 946 deaths across 27 countries in six global regions, reflecting a global case fatality rate of approximately 36%, as of 2025.[1] The highest number of cases has been documented in Saudi Arabia which has reported 2,218 cases, with 865 deaths as of 2025, with a 39% case fatality rate.[2] In 2015, South Korea experienced a major nosocomial outbreak, revealing

the high potential for rapid human-to-human transmission in healthcare setting.[3] Since 2019, no confirmed cases have been reported outside the Middle East.

In 2023 and 2024, the number of pilgrims traveling to perform the Hajj from around the world was approximately 899,353 and 1,655,188, respectively. Thailand has been allocated a quota of roughly 13,000 pilgrims per year. In practice, the number of Thai pilgrims traveling was 3,738, 11,893, 7,738, and 6,603 persons in 2022, 2023, 2024, and 2025, respectively.[4–9]

In Thailand, the number of Muslims in Pattani, Yala, and Narathiwat provinces was 44% of the total Muslims in Thailand.[10] These provinces are considered high-risk due to their high Muslim population density. Moreover, Thailand, a regional travel hub and destination for Muslim pilgrims traveling to and from the Middle East, remains at risk for MERS importation. The reports from the Division of Epidemiology of the Thai Department of Disease Control showed that, from 2015 to the present, there were 1,007 imported suspected cases in Thailand, comprising 532 males and 475 females, including three confirmed cases. As of 2025, no new confirmed cases have been reported in Thailand since 2016.[4] Nevertheless, the risk persists due to the arrival of international travelers, particularly Hajj and Umrah pilgrims from high-risk regions, as well as tourists visiting high-risk areas before traveling to Thailand.

The International Health Regulations (IHR) 2005 and the Joint External Evaluation guide all member countries to emphasize the importance of strengthening surveillance, laboratory diagnostics, early detection at the point of entry, and risk communication to mitigate the threat of emerging infectious diseases, such as MERS.[5,6] Nationally, according to the Communicable Disease Act B.E. 2558 (2015), MERS is classified as one of fourteen dangerous communicable diseases. As such, it is mandatory to implement surveillance, prevention, and control measures for this disease under the legal framework.[7]

The objectives of this study were 1) to estimate the extent of a potential spread following importation of a MERS outbreak in Thailand using predictive modeling and 2) to assess Thailand's preparedness through qualitative analysis of policy, systems, and stakeholder opinions to provide evidence-based recommendations and policy guidance for the Department of Disease Control and the Ministry of Public Health to develop effective disease control strategies, and reduce the burden on improving people's quality of life and well-being.

Methods

Locations and Timeframe

This study was conducted at the Ministry of Public Health, Nonthaburi, Thailand, between October 2024 and May 2025. The preparatory activities, including problem identification, objective setting, literature review, study design, and questionnaire design and validation, were conducted between October and December 2024.

Study Design

The study employed a mixed-methods study, combining quantitative and qualitative studies. The data were collected from January to May 2025.

Quantitative study

The quantitative study was conducted between January and May 2025, utilizing a predictive modeling study based on the deterministic Susceptible-Exposed-Infectious-Recovered (SEIR) compartmental model. This study developed a modified SEIR model based on literature reviews to simulate MERS-CoV transmission in the three southern provinces of Thailand.[8–10] The model incorporated additional compartments to reflect quarantine and isolation measures and separately represented Muslim and non-Muslim populations to account for differences in contact patterns.

In the model, individuals transition from the susceptible (S) compartment to the exposed in the community (Ec). After exposure, individuals may either remain in the community or enter quarantine (Eq). Quarantined individuals who become infectious are transferred directly to isolation, either as symptomatic (Iisq) or asymptomatic (Iiaq). Other infectious individuals are categorized as symptomatic in the community (Ics), symptomatic in isolation after community exposure (Iisc), and asymptomatic in the community (Ica) or in isolation (Iiac). Symptomatic individuals may progress to hospitalization (H), with outcomes of either recovery (R) or death (D). All recovered individuals move to the R compartment, representing recovery and being immune (Figure 1).
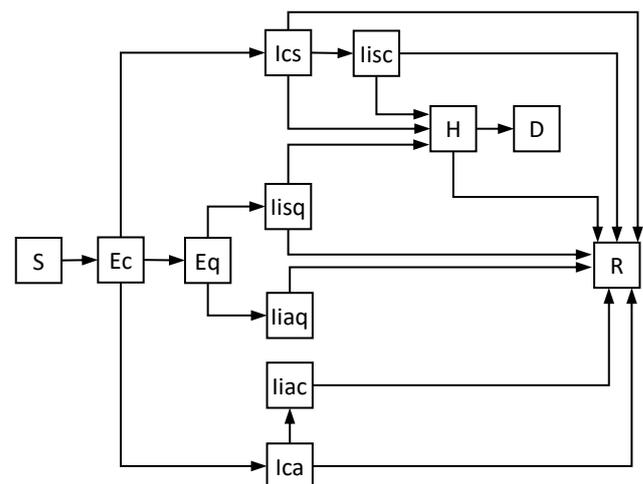

Figure 1. Model framework of MERS-CoV situation in three southern provinces of Thailand

The total modeled population was 2,111,820 individuals, comprising 1,567,756 Muslims and 544,064 non-Muslims. The model was initialized with

10 symptomatic and 10 asymptomatic MERS-CoV-infected Muslim individuals, while the rest of the population began as being susceptible. The simulation proceeded in daily time steps over a period of 120 days. The model assumed a closed population with no births, deaths unrelated to MERS-CoV, or migration. Mixing was considered homogeneous within Muslim and non-Muslim groups, with limited cross-group contacts. No model fitting was performed, as Thailand has not experienced a MERS-CoV outbreak to provide calibration data. Parameter values were taken directly from published literature and expert consensus and applied as fixed inputs for all simulations. Key parameters, system variables, and governing equations are detailed in Supplementary Tables 1–2.

The model was used to evaluate five intervention scenarios to explore the impact of different public health measures on MERS-CoV transmission (Supplementary Table 3). Scenario A served as the baseline with no interventions, reflecting the natural course of transmission without additional control measures. Scenario B examined the effect of increasing the proportion of severe cases admitted to high-resource hospitals, which have a lower case fatality rate compared with low-resource hospitals. Scenario C simulated increased quarantine coverage, increasing the proportion of exposed individuals identified and quarantined before becoming infectious in the community. Scenario D assessed the impact of earlier case detection by shortening the delay between infectiousness and isolation for both symptomatic and asymptomatic individuals, thus reducing onward transmission. Scenario E combined all major interventions—increased access to high-resource hospitals, increased quarantine coverage, and earlier detection—to reflect an integrated control strategies. The reproductive number (R) was classified into three scenarios (R=1, R=2, R=3) based on expert opinion and literature review.[11]

Qualitative study

The qualitative study was conducted between March and May 2025 as follows.

The documentary review part was conducted between March and May 2025 to assess Thailand's existing policies, plans, and operational frameworks related to MERS preparedness, as well as those of international organizations. The reviews included internal guidelines, national strategic plans, WHO technical reports, and MERS-specific plans and procedures, as well as original articles, totaling 29 online documents.[1,3,4,12–37]

Between April and June 2025, in-depth interviews were conducted using a semi-structured questionnaire to explore the views of participants, including policymakers, experts, and relevant officers. The interviews were informal, allowing participants to share their insights and experiences freely. This study collected data from 21 participants, including the director general of the Department of Disease Control, two deputy director generals of the Department of Medical Sciences and Health Service Support, eight directors of Department of Disease Control, three senior experts of Department of Medical Services and Disease Control, one deputy director of provincial health office, and four local public health officers of Department of Disease Control, and international organizations (one from the World Health Organization in Thailand and one from Thailand-MoPH-U.S. CDC Collaboration (TUC)).

Data Analysis

For Quantitative data, this study used predictive modeling based on the SEIR model, using the freeware of Vensim, which can be downloaded at URL <https://vensim.com/free-downloads/>.

Qualitative data were collected as part of the data triangulation process. A structured approach was applied to identify, select, and examine relevant documents, including national strategic plans, guidelines for MERS surveillance, World Health Organization (WHO) technical reports, and protocols.

This study analyzed documentary reviews by using a thematic analysis approach. According to the WHO International Health Regulations (IHR) core capacities, a deductive thematic analysis was conducted using pre-established themes.[33] Each extracted piece of content was coded into one or more IHR categories, and thematic analysis involved summarizing the content under each theme. Representative quotations from documents were used to illustrate key findings. Triangulation with qualitative data from in-depth interviews was used to enhance validity and provide a more comprehensive assessment.

This study employed thematic analysis for the in-depth interview data. It involved data preparation, coding, theme identification, including key themes and sub-themes, interpretation, and reporting of the results, which was supported by representative quotes. Additionally, this study employed data triangulation for verification purposes.

Results

Quantitative Study

The simulation of MERS-CoV outbreak in three southern provinces of Thailand showed that early case

detection and combined interventions consistently reduced the epidemic burden across all reproductive number scenarios (R=1, 2, 3). Under baseline conditions, the peak number of daily new infectees reached 0.84, 1.80, and 3.00 for R=1, 2, and 3, respectively, with peaks occurring on day 7–11. Increasing quarantine coverage modestly reduced cumulative infections, whereas early detection and combined strategies had the greatest effect, lowering cumulative infections (including initial imported cases) from 37.67–241.65 in

the baseline to 29.22–69.03 and 28.55–54.73, respectively. For severe cases, the baseline cumulative burden ranged from 13.66 to 79.92, but this was reduced to 8.70–16.22 with combined interventions. Mortality was also reduced with cumulative deaths decreased from 6.82–37.56 in the baseline to 3.76–7.00 under combined interventions. Peak timing of severe cases and deaths was delayed under higher R values, but occurred earlier when early detection was implemented (Table 1).

Table 1. Simulation results under different intervention scenarios, as indicated by the basic reproduction number (R)

Outcome	Scenario	R=1	R=2	R=3
Peak number of new daily infectees*	Baseline (A)	0.84	1.80	3.00
	High-resource hospital admission (B)	0.84	1.80	3.00
	Increased quarantine coverage (C)	0.84	1.75	2.77
	Early case detection (D)	0.62	1.30	2.05
	Combined interventions (E)	0.63	1.30	2.01
Cumulative number of infectees†	Baseline (A)	37.67	79.97	241.65
	High-resource hospital admission (B)	37.67	79.97	241.65
	Increased quarantine coverage (C)	35.37	60.12	105.90
	Early case detection (D)	29.22	43.61	69.03
	Combined interventions (E)	28.55	39.68	54.73
Incidence proportion (per 100,000 population)§	Baseline (A)	1.78	3.79	11.44
	High-resource hospital admission (B)	1.78	3.79	11.44
	Increased quarantine coverage (C)	1.67	2.85	5.01
	Early case detection (D)	1.38	2.07	3.27
	Combined interventions (E)	1.35	1.88	2.59
Peak number of new daily severe cases	Baseline (A)	0.82	0.86	0.95
	High-resource hospital admission (B)	0.82	0.86	0.95
	Increased quarantine coverage (C)	0.81	0.85	0.90
	Early case detection (D)	0.57	0.61	0.66
	Combined interventions (E)	0.57	0.60	0.66
Cumulative number of severe cases	Baseline (A)	13.66	27.86	79.92
	High-resource hospital admission (B)	13.66	27.86	79.92
	Increased quarantine coverage (C)	12.52	20.30	34.61
	Early case detection (D)	8.97	13.22	20.73
	Combined interventions (E)	8.70	11.90	16.22
Peak number of new daily deaths	Baseline (A)	0.20	0.26	0.44
	High-resource hospital admission (B)	0.17	0.23	0.37
	Increased quarantine coverage (C)	0.19	0.24	0.33
	Early case detection (D)	0.15	0.18	0.23
	Combined interventions (E)	0.12	0.15	0.19
Cumulative number of deaths	Baseline (A)	6.82	13.80	37.56
	High-resource hospital admission (B)	5.89	11.92	32.45
	Increased quarantine coverage (C)	6.26	10.13	17.16
	Early case detection (D)	4.48	6.61	10.33
	Combined interventions (E)	3.76	5.14	7.00

The number of new daily severe cases did not include the initial 20 imported cases. †Cumulative number of infectees included the initial 20 imported cases (10 symptomatic and 10 asymptomatic). §Incidence proportion (per 100,000) was calculated as the cumulative number of infectees divided by total population (2,111,820) × 100,000.

The epidemic curves (Figure 2) show distinct effects of interventions on transmission. Scenarios A (baseline) and B (high-resource hospital admission) produced identical infection trajectories, with cumulative cases rising steadily, especially when R=3. Scenario C

(increased quarantine coverage) moderately flattened the curves, while Scenario D (early detection) and Scenario E (combined interventions) further suppressed transmission, with infections plateauing earlier.
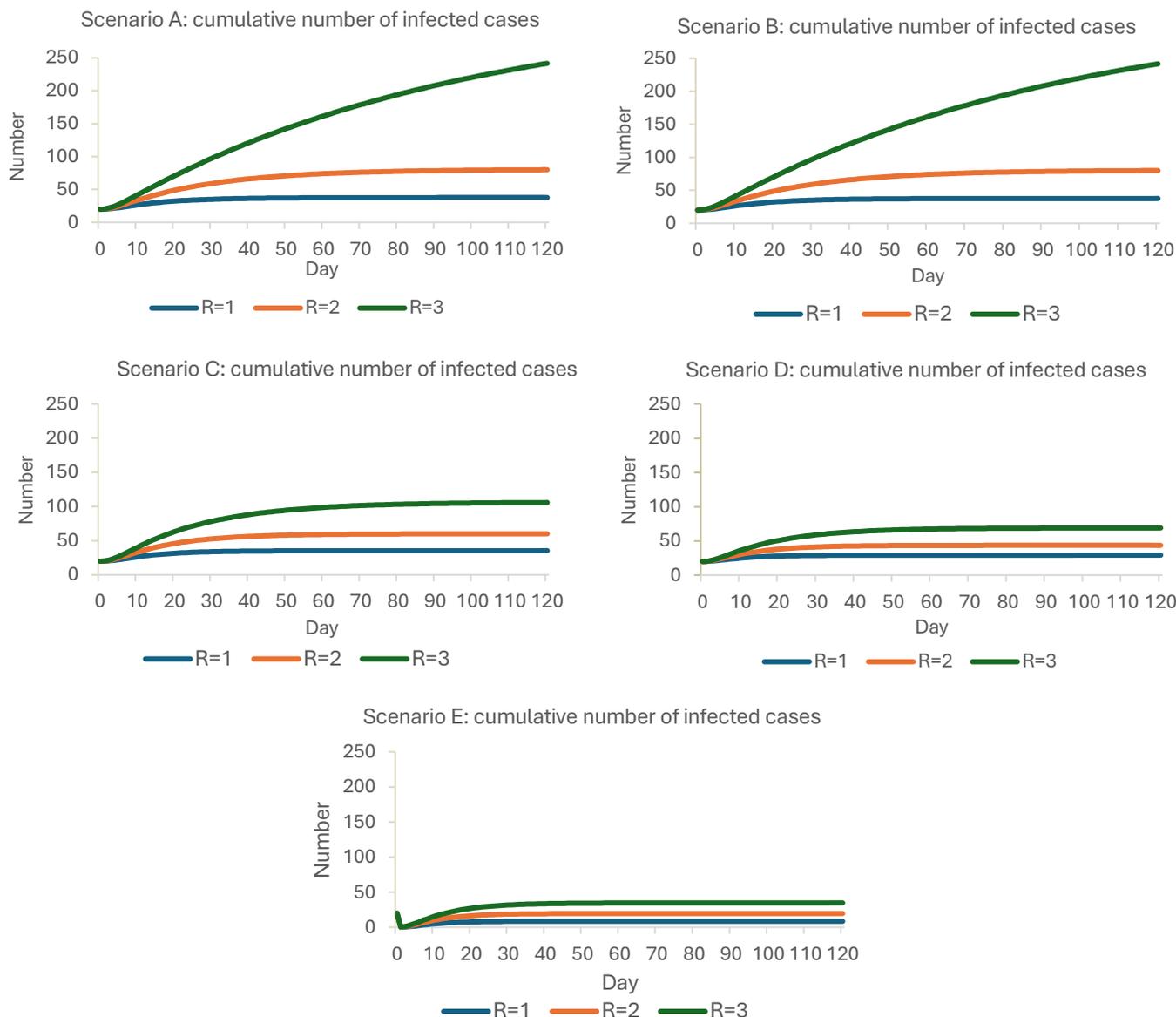
Figure 2. Scenario A: Baseline, Scenario B: High-resource hospital admission, Scenario C: Increased quarantine coverage, Scenario D: Early detection and Scenario E: Combined interventions

Qualitative Study

Documentary review

During March and April 2025, a review of 29 online documents was conducted based on the eight WHO IHR core capacities theme. These documents were categorized into the eight WHO IHR core capacity themes, including surveillance, response, preparedness, risk communication, human resources, laboratory, point of entry, and health information systems. These findings indicated that Thailand has established MERS preparedness relying on the eight WHO IHR core capacities; although MERS-specific updates have been limited since 2016. The challenges included resource allocation, developing appropriate risk communication strategies for the different risk groups, integrated exercise training, laboratory-based/ syndromic surveillance, and digital system integration.

In-depth interviews

The characteristics of participants showed that most participants were men (61.9%), with a median age of 50 years (range, 25–63 years). The majority of educators held a doctoral degree or its equivalent (n=16, 76.2%), followed by a bachelor's degree (n=4, 19.0%), and a master's degree (n=1, 4.8%). Most participants had more than 10 years of experience (n=16, 76.2%), followed by 5–10 years of experience (n=1, 4.8%), and less than 5 years (n=4, 19.0%). According to the workplace, most of them were affiliated with the Department of Disease Control (n=15, 71.43%), followed by the Office of the Permanent Secretary, Ministry of Public Health, (n=1, 4.76%), Department of Medical Science (n=1, 4.76%), Department of Medical Services (n=1, 4.76%), Department of Health Service Support (n=1, 4.76%), TUC (n=1, 4.76%), and WHO (n=1, 4.76%).

The results of interviews with 21 participants were described as six main themes and sub-themes, including policy, plans, and governance (national strategy, plans for MERS), operational and system gaps (surveillance systems, laboratory capacity, risk communication), human resources and capacity building (staff readiness, training systems, joint investigation team mechanisms), resource and medical supply management (personal protective equipment stockpiles, operational support), coordination and collaboration (domestic and international linkage, command structures), and technology and information systems (use of digital tools and technology, data fragmentation). It showed that operational gaps existed in strengthening specific MERS surveillance, laboratory capacity, MERS-specific training, and coordination mechanisms. Technology was underutilized due to siloed data systems. Stakeholders demonstrated the importance of integrated exercises, updated concept of operations, and enhanced local engagement at the community level.

Discussion

The results have also highlighted that Thailand has partial readiness in responding to the MERS outbreak, primarily related to improvements made during the COVID-19 pandemic and proactive preparedness, particularly in high-risk regions. However, gaps remain in operational aspects.

The SEIR models demonstrated the importance of early detection, quarantine, increased admission to high-resource hospitals, and integrated interventions in minimizing MERS-CoV transmission, particularly in high-risk provinces. The timely implementation of combined interventions (all major interventions) was more effective than isolated quarantine measures alone. The early case detection alone was a good measure to reduce the peak of infectees and severe cases compared to other measures alone. The model supported the use of targeted preparedness strategies and investment in surveillance, diagnosis, and community engagement for a timely public health response.

The modeling indicated the likelihood of MERS outbreak in three southern provinces, which demonstrated that MERS outbreak is less likely to be widely transmitted, especially nationwide. It is relevant to findings from the study of MERS in South Korea, where community transmission was limited and most widespread transmission occurred in healthcare settings.[3] Furthermore, the study has emphasized the importance of MERS context-specific preparedness, particularly in areas with high risk,

such as the southern border provinces. According to literature reviews, the results indicated that tertiary or general hospitals were well-prepared for MERS, while primary and secondary hospitals were less prepared. The results showed that the parameters aligned with those from a study conducted in South Korea during the 2015 MERS outbreak and were relevant to the hypothesis of the SEIR modeling.[3] Modeling findings has emphasized the importance of timely isolation, particularly for both symptomatic and asymptomatic cases, in minimizing the size of the outbreak.

Lessons learned from the COVID-19 pandemic surveillance and disease control have indicated that suitable surveillance for emerging diseases is necessary. MERS showed a similar mode of transmission to COVID-19, it has a higher case fatality rate and is associated with high care costs, even though it is less likely to be widely transmitted. MERS preparedness remains a significant consideration. Additionally, it is one of fourteen dangerous communicable diseases listed under the Communicable Disease Act B.E. 2558 (2015). However, to date the restriction on surveillance has been low, which may have contributed to the system's limited sensitivity in detecting diseases effectively. This is also the case for MERS, for which there have been no outbreaks in Thailand since 2016. Its surveillance is included in the national communicable disease surveillance system, which currently covers 176 diseases.[13] To address this issue, a dedicated surveillance system for dangerous communicable diseases, including MERS, should be established to facilitate early and rapid detection of such diseases. This system could adapt and leverage the surveillance, prevention, and control measures that were strengthened during the COVID-19 pandemic. It will require a lesser increase in budgetary and resource burden compared to strengthening the entire notifiable disease surveillance, in addition to practical monitoring for those dangerous communicable diseases.

Qualitative findings have revealed gaps in MERS-specific surveillance systems, laboratory capacity, health literacy among high-risk groups, preparedness for resources, and data system fragmentation. Surveillance, particularly syndromic and laboratory-based, was identified as the most critical area requiring strengthening. Additionally, syndromic and laboratory-based screening at the points of entry should be considered for efficient measures, particularly in the early detection of international travelers and Hajj pilgrims, to reduce risk and lower

the budget for tracing and quarantine. These findings aligned with the six building blocks for a health system, as recommended by the World Health Organization.[38]

The consistency of the coordination mechanisms indicated the challenge of coordination. The protocols within the Department of Disease Control have not been regularly updated. Therefore, this results in gaps in coordination and timely response. Additionally, health volunteers played a key role in the gap between policy and practice, thereby enhancing the surveillance system and risk communication. It is in consideration of supporting this community-level network to remain effective and integrate with the national preparedness strategy in disease control, as seen in the role of health volunteers in Thailand, who played a key role in surveillance and response to the pandemic.[31,34]

Another gap identified was the fragmentation of data across different units within the health system, leading to data delays, duplication, and incomplete information. Fragmentation of data was related to effective management in public health emergency management.[35–37]

Limitations

This study has some limitations. The SEIR modeling is based on hypothetical parameters regarding high-risk populations, MERS characteristics, and disease control measures, which were based on available data from literature reviews, may not accurately reflect real-world dynamics. This study primarily involved the perspectives of policymakers and experts, which may introduce information biases. Another limitation is that Thailand has never experienced indigenous transmission or a large-scale outbreak of MERS-CoV. Therefore, both the modeling component and the qualitative analysis were based on assumptions drawn from the experience of other countries or from previous respiratory outbreaks in Thailand. However, it can be reasonably defended that such knowledge and prior experience are relevant and applicable, given the similarities in transmission mechanisms and public health response requirements for emerging respiratory pathogens.

Recommendations

Recommendations include strengthening early detection, surveillance, laboratory capacity, and risk communication; regular preparedness plans, standard operating procedure, training, and coordination mechanisms; ensuring adequate resources and intersectoral collaboration and coordination; and advancing national data integration. Future studies should assess practical preparedness at regional levels and readiness for other emerging diseases.

Conclusion

The mixed-methods study assessed the potential spread and preparedness for the MERS outbreak in Thailand. SEIR modeling indicated that the baseline scenario resulted in the highest number of infections and deaths, while early detection and combined interventions reduced the outbreak size across all R values, with nationwide spread being unlikely. The qualitative findings revealed strengths in national strategies, experienced personnel, and coordination. However, gaps were in MERS-specific surveillance, laboratory capacity, health literacy among high-risk groups, resource preparedness, and fragmented data systems.

Author Contributions

Rapeepan Phothong: Conceptualization, methodology, writing—original draft, writing—review & editing, supervision, validation, project administration. **Natthaprang Nittayasoot:** Conceptualization, methodology, writing—original draft (methodology), writing—review & editing. **Panithee Thammawijaya:** Conceptualization, methodology, validation.

Ethical Approval

This study was conducted as part of the Department of Disease Control's mandate in communicable disease surveillance, prevention, control, and public health preparedness. This was formally approved as routine public health activity and was therefore exempt from ethical review for research in humans.

Informed Consent

Data collection was conducted under an approved program with official permission letters obtained from legal authorities. Accordingly, individual informed consent from participants was not required.

Data Availability

The quantitative data supporting the findings of this study are available in the supplementary material of this article. The data from documentary reviews were derived from publicly available resources and cited in the references. The in-depth interview data are not publicly available due to privacy and ethical restrictions, but may be available from the corresponding author upon reasonable request.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this article.

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Declaration of Generative AI and AI-assisted Technologies in the Writing Process

During the preparation of this work, the authors used generative AI tools (ChatGPT and Grammarly) to enhance clarity and correct grammatical errors. The content produced by these tools was reviewed and edited by the authors, who accept full responsibility for the final text.

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