المركز الخليجي للوقاية من الأمراض ومكافحتها
Gulf Center For Disease Prevention And Control

مجلس الصحة
لدول مجلس التعاون
Gulf Health Council

MERS Prevention and Control

in the Gulf Cooperation Council Countries

Successful experiences, lessons learned, gaps and opportunities

TECHNICAL REPORT

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Acknowledgements

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Foreword

MERS-CoV emerged in the Kingdom of Saudi Arabia in 2012 and continues to be detected predominantly in some countries of the Gulf Cooperation Council (GCC) until the end of 2024. Many discoveries have been made and lessons were learned through decisions taken and efforts made to prevent and control the disease in the Region. These experiences serve as a best practice case study for the regional and global public health community to learn from, particularly as Middle East respiratory syndrome coronavirus (MERS-CoV) continues to be a high threat pathogen of global concern.

It is with great pleasure that we present this report to you, a comprehensive documentation of the GCC countries experience, which is both thought-provoking and insightful. This report was based on a designed questionnaire reviewed and filled-in by members of GCC country technical representatives in the Gulf CDC Technical Working Group for One Health Emergency. Within this report, you will find information, gathered and synthesized from a variety of individuals who were involved in the planning and execution of the MERS preparedness and response efforts. We hope this report inspires you to join our efforts in preventing, detecting and responding to MERS-CoV and any emerging zoonotic pathogen in the GCC countries and beyond.

Best regards,

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Executive Summary

This report provides an overview of key insights and observations on emergency preparedness for emerging and re-emerging zoonotic diseases, drawing from diverse practices and challenges identified across multiple sectors. It aims to collate and present the experiences of public health stakeholders in the Gulf Cooperation Council (GCC) countries that responded to outbreaks caused by Middle East respiratory syndrome coronavirus (MERS-CoV) between 2012 and 2024. By reviewing these experiences, the report is intended to serve as a resource for countries revising their emerging infectious diseases preparedness plans and strategies.

The findings emphasize the importance of a comprehensive, multisectoral approach that integrates human, animal, and environmental health systems under the One Health framework. While recognizing that member states operate within varying capacities and contexts, this report highlights potential areas for enhancing preparedness and response mechanisms.

The report is organized into thematic sections, reflecting critical components of emergency preparedness: Overing governance, Plans and Policies, and health workforce. Then addressing surveillance, clinical case management, laboratory diagnostics, healthcare facilities and infection prevention and control. The report also briefly addressed the research and development efforts, supply chain management, risk communication and community engagement, and One Health activities.

Each section provides insights that were shared from member states as well as their response experience, the gaps and opportunities identified, offering member states a resource to tailor their strategies based on individual contexts. While not all observations will be universally applicable, they serve as a repository of practices and lessons learned that may inspire future improvements in regional and global health security, particularly when dealing with zoonotic diseases following the One Health approach.

Content

I.Abbreviations

ADAFSA	Abu Dhabi Agriculture and Food Safety Authority
AI	Artificial intelligence
ARI	Acute respiratory infection
CAMENET	Camel Middle East Network
CAP	The College of American Pathologists
CCHF	Crimean–Congo hemorrhagic fever
CDC	Center for Disease Control and Prevention
COVID	Coronavirus disease
CPIC	Certified Professional Infection Control
CPHL	Central Public Health Laboratories
ECMO	Extracorporeal Membrane Oxygenation
ELISA	Enzyme-Linked Immunosorbent Assay
EMC	Erasmus Medical Center
EMPHNET	The Eastern Mediterranean Public Health Network
EMRO	WHO Regional Office for the Eastern Mediterranean
FAO	Food and Agriculture Organization
FETP	Field Epidemiology Training Program
GCC	Gulf Cooperation Council
GISAID	Global Initiative on Sharing All Influenza Data
Gulf CDC	Gulf Center for Disease Prevention and Control
GHC	Gulf Health Council
HEPA	high efficiency particulate air [filter]
HESN	[Saudi] Health Electronic Surveillance Network
ICT	Immunochromatographic test
ICU	Intensive care unit
IFN	Interferon
IHR	International Health Regulations
ILI	Influenza-like Illness(es)

I.Abbreviations

IPC	Infection prevention and control M
ISO	International Organization for Standardization
JRA	Joint Risk Assessment
KAIMRC	King Abdullah International Medical Research Center
MERS-CoV	Middle East Respiratory Syndrome Corona Virus
MS	Member States
MVA	Modified Vaccinia Ankara
NUPCO	National Unified Procurement Company
OCT	Outbreak Control Taskforce
PAPR	Powered Air-Purifying Respirator
PCR	Polymerase Chain Reaction
PHA	Public Health Authority
PHL	Public Health Laboratory
PPE	Personal Protective Equipment
RNA	Ribonucleic acid
RT	Reverse Transcriptase
SARI	Severe Acute Respiratory Infections
SARI-IS	Severe Acute Respiratory Infections – Intensive Surveillance
SARS	Severe Acute Respiratory Syndrome
UAE	United Arab Emirates
UNEP	United Nation Environmental Program
WGS	Whole Genome Sequencing
WHO	World Health Organization
WOAH	The World Organization for Animal Health

II.Introduction

The main objective of this document is to summarize the experience and lessons learned by the Gulf Cooperation Council Member States (GCC MS) in responding to Middle East Respiratory Syndrome Corona virus (MERS-CoV). As an endemic zoonotic disease in the GCC countries, the experience attained from responding to MERS outbreaks is unique and sets a benchmark for addressing emerging and re-emerging zoonotic diseases. MERS has exemplified the importance of applying the One Health approach to tackle zoonotic diseases. This is evident in how multisectoral collaboration can be the guiding principle in surveillance, diagnostics, infection prevention and control, risk communication and many other pillars of emergency preparedness. This document is tailored for specialized local, regional and international policymakers in public health and public health practitioners particularly those involved in implementing the One Health concept to address threats posed by zoonotic diseases.

It is well known that the existence of legislative mandates and well-formed governance structure are essential to respond to communicable diseases, and this has guided the public health responses for MERS across the GCC MS. These legislative mandates have also guided the development of tailored national policies and plans specific to address threats imposed by MERS. To ensure effective response, the GCC MS have made notable efforts to enhance workforce capacities by training, certifying, and retaining multisectoral personnel, improving their specialized skills, and increasing awareness of MERS among medical, animal health, public health, and other relevant stakeholders. As a result, improved active and passive surveillance were applied, efficient emergency response, tailored communication to the majority of the subpopulation segments, optimized management, and improved infection prevention and control (IPC) practices on multisectoral levels. Also, some key discoveries, such as the identification of the intermediate host, were made as a result of dedicated research and development in MERS-CoV, which have informed the prevention and control efforts regionally and globally. MERS response has set the benchmark for establishing and managing outbreaks based on the One Health concept.

The lessons learned from MERS response, particularly in building local capacities and coordination in all aspects, were instrumental and well prepared the GCC MS to better respond to COVID-19 pandemic and set the standard to respond to any potential threats caused by emerging and re-emerging zoonotic disease.

This document also outlines some of the challenges that were observed when reviewing the management of MERS outbreaks. Identifying these challenges can help mitigating future risks imposed by zoonotic diseases outbreaks. Lastly, this document aims to lay the foundation for the ways forward to better manage emerging and epidemic-prone zoonotic diseases in the GCC MS and beyond.

III. Background

MERS-CoV Discovery and Identification

In 2012, a novel coronavirus, later named MERS-CoV, was identified in a 60-year-old man in Saudi Arabia who developed acute pneumonia and renal failure, resulting in death. Genetic analysis revealed that the virus, initially designated HCoV-EMC, was a novel betacoronavirus closely related to bat coronaviruses [1]. The virus, which replicated readily in cell culture and caused cytopathic effects, presented with clinical symptoms such as fever, cough, and shortness of breath.

Virology

MERS-CoV belongs to the Coronaviridae family and possesses a large RNA genome ranging from 26 to 33 kb, with G+C contents varying between 32% and 43% [2,3]. This virus is classified within the 2C lineage of betacoronaviruses [4], closely related to certain bat coronaviruses, yet distinct from other human betacoronaviruses like SARS-CoV. The primary receptor for MERS-CoV is dipeptidyl peptidase 4 (DPP4), which facilitates viral entry into host cells [5,6]. The virus can infect various human cell lines, predominantly targeting respiratory epithelial cells, macrophages, and dendritic cells [7]. MERS-CoV also exhibits the ability to infect cells from a range of non-human species, including non-human primates, pigs, bats, civets, rabbits, and horses [8,9]. The virus's genome encodes structural proteins, such as the spike (S), membrane (M), nucleocapsid (N), and envelope (E) proteins, alongside several accessory proteins [10].

Transmission and Epidemiology

MERS-CoV transmission primarily occurs through zoonotic and limited human-to-human pathways. Dromedary camels are recognized as the primary intermediate host for MERS-CoV, with the virus detected in their nasal and mucosal secretions, as well as stool. Documented cases of camel-to-human transmission include instances where genetic sequencing confirmed identical MERS-CoV isolates in infected humans and camels [11]. Human-to-human transmission typically occurs in close-contact settings, such as within households or healthcare environments, and is often facilitated by respiratory secretions [12]. Studies have demonstrated seronegativity for MERS-CoV in other domestic animals, such as sheep, goats, cattle, and equids in various regions [13-15]. Camels consistently exhibit high seropositivity [12], suggesting a long-standing presence of the virus in these animals (Figure 1). The risk of transmission increases with practices involving close contact with camels, such as training and milking, and the consumption of raw camel products [16].

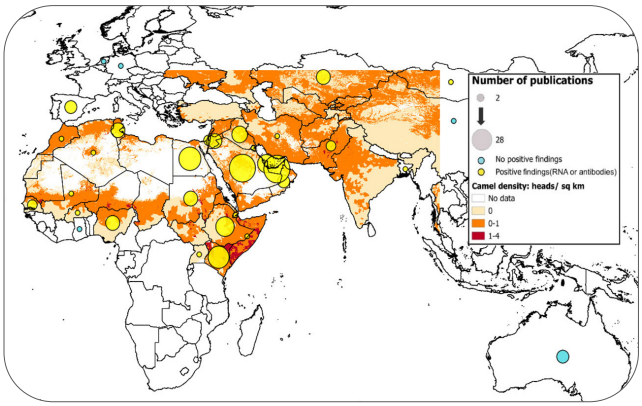
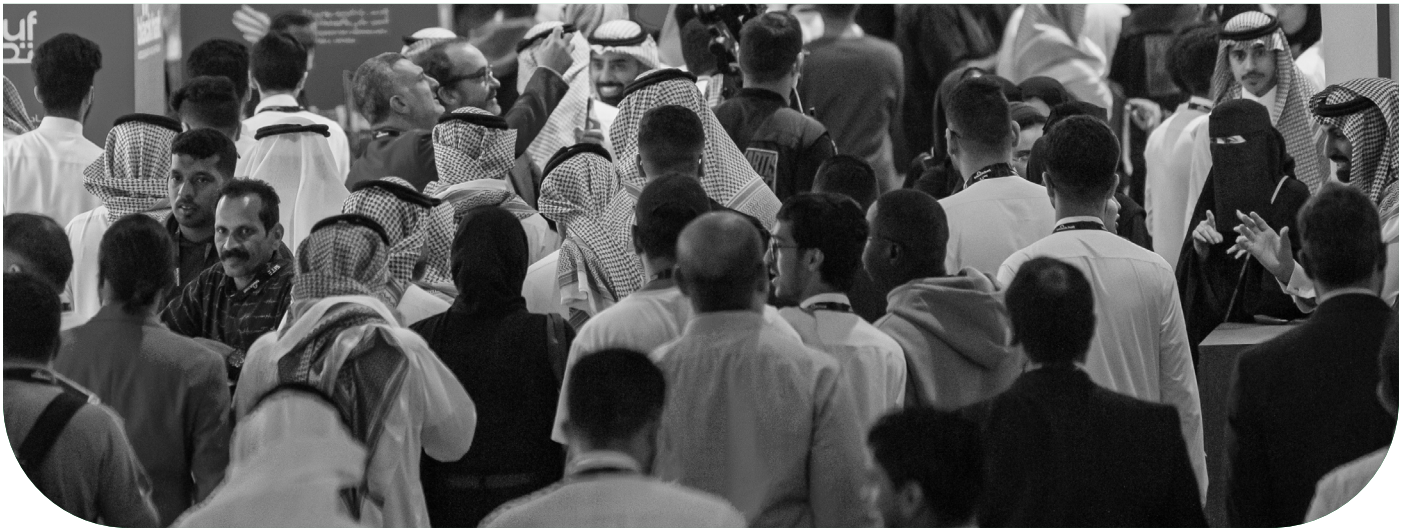


Figure 1: Results of published MERS-CoV livestock field surveys conducted up to Feb 2024. Adapted from [17].

The virus was first identified in 2012, and as of the date of this report, over 2,600 laboratory-confirmed cases have been reported, resulting in at least 858 documented fatalities [16]. MERS outbreaks have predominantly occurred in the Middle East, particularly in Saudi Arabia, which accounts for approximately 85.8% of reported cases [16] (Table 1 and Figure 2). However, South Korea had the only large outbreak outside the Middle East, in 2015, with 186 cases across 16 hospitals and a mortality rate of 19.4% [18]; in addition, imported cases have been identified in various countries worldwide such as in the United States, and European nations [16,18] (Figures 3 & 4). The virus has demonstrated a high case-fatality rate of approximately 35%, and exhibits a higher prevalence in males, with individuals aged 50-59 years-old at the highest risk or acquiring the infection [19]. Seasonal peaks in MERS cases typically occur between April and June, potentially linked to camel birthing seasons when young camels are more susceptible to infection [4,20] mostly during winter season. While human-to-human transmission can occur, particularly in healthcare settings, such instances remain relatively limited [12,21]. Enhanced surveillance and case detection have contributed to the identification of cases, particularly in regions with active trade in camels, such as the Gulf states [4].

Table 1: *Number of reported MERS cases in humans by country and dates of first and most recent observations in the GCC MS until Sep 2024. Adapted from [17].*

Country	Cumulative number of confirmed MERS human cases	First observation	Last Observation
Saudi Arabia	2,204	13/06/2012	10/04/2024
United Arab Emirates	94	19/03/2013	10/07/2023
Qatar	28	15/08/2013	18/03/2022
Oman	26	26/10/2013	28/12/2022
Kuwait	26	30/10/2013	08/09/2015



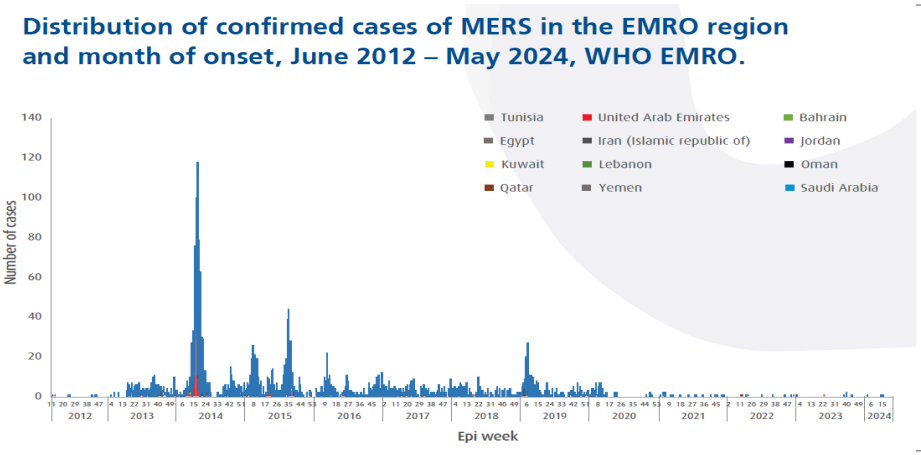


Figure 2: *Distribution of confirmed cases of MERS in the GCC and month of onset, April 2012 – Aug 2024, by the WHO EMRO, Amal Bakarat.*

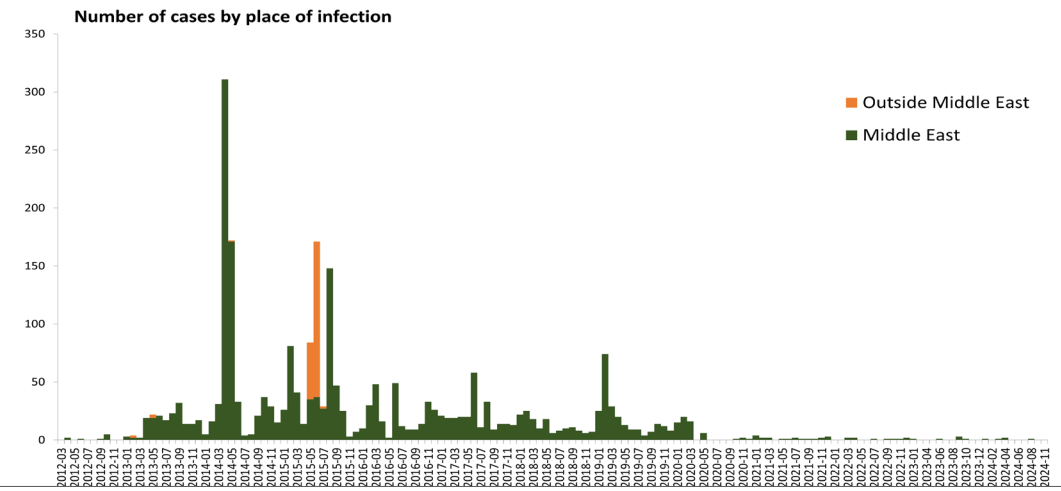


Figure 3: *Distribution of confirmed cases of MERS by place of infection and month of onset, April 2012 – November 2024. Adapted from [22].*

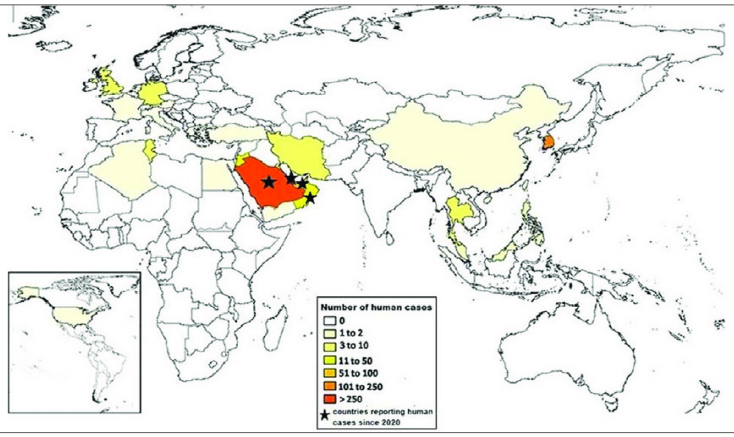


Figure 4: *Global distribution of human cases of MERS. Stars highlight countries reporting human cases since 2020 (UAE, Saudi Arabia, Oman, and Qatar). Adapted from [17].*

Pathogenesis and Mechanism of Infection

The pathogenesis of MERS-CoV in humans is predominantly in the lower respiratory tract [23], with viral replication occurring in respiratory epithelial cells, macrophages, and dendritic cells. This replication triggers the production of pro-inflammatory cytokines and induces apoptosis in T lymphocytes, contributing to the disease's severity. MERS-CoV can also infect other organs, including the kidneys, intestines, liver, and histiocytes [7] with organ failure documented in severe cases. Viral shedding from respiratory secretions can continue intermittently for several weeks, raising concerns about transmission, including from asymptomatic individuals [11,24,25]. In camels, the virus typically causes mild or no symptoms, complicating clinical diagnosis [11]. Bats are presumed to be the original reservoir, based on genetic analysis, and may serve as carriers without showing signs of illness [26]. The spike protein, particularly its receptor-binding domain, is critical for host cell entry and cross-species transmission, with certain mutations enhancing the virus's pathogenicity and transmission efficiency [27]. Furthermore, the detection of homologous genomic sequences in stool and nasal secretions of dromedaries highlight their role in both zoonotic and inter-human transmission dynamics [16].

Diagnostics

MERS-CoV belongs to the Coronaviridae family and possesses a large RNA genome ranging from 26 to 33 kb, with G+C contents varying between 32% and 43% [2,3]. This virus is classified within the 2C lineage of betacoronaviruses4, closely related to certain bat coronaviruses, yet distinct from other human betacoronaviruses like SARS-CoV. The primary receptor for MERS-CoV is dipeptidyl peptidase 4 (DPP4), which facilitates viral entry into host cells [5,6]. The virus can infect various human cell lines, predominantly targeting respiratory epithelial cells, macrophages, and dendritic cells [7]. MERS-CoV also exhibits the ability to infect cells from a range of non-human species, including non-human primates, pigs, bats, civets, rabbits, and horses [8,9]. The virus's genome encodes structural proteins, such as the spike (S), membrane (M), nucleocapsid (N), and envelope (E) proteins, alongside several accessory proteins [10].

Therapeutics

Therapeutic options for MERS have largely focused on the use of antiviral drugs and immunomodulatory treatments. Among antivirals, ribavirin combined with interferons (IFNs) has been extensively studied, though with mixed results. Some studies indicate no significant reduction in mortality when compared to supportive care [34,35], while others report slight improvements in early mortality rates with specific combinations like ribavirin and IFN-α 2a [36]. However, these findings are often limited by small sample sizes and potential confounding factors [37]. Lopinavir/ritonavir and oseltamivir have also been employed, primarily as empiric treatments, though there is no clear evidence of their efficacy against MERS [30,38]. Immunomodulatory agents like corticosteroids have been used, but they are generally not recommended due to potential adverse effects and limited evidence of benefit [37]. Supportive care remains the cornerstone for managing severe cases, with intervention such as mechanical ventilation and extracorporeal membrane oxygenation (ECMO) playing critical roles, particularly in the absence of definitive antiviral therapies [37,39].

Vaccines

Since MERS-CoV was first identified in Saudi Arabia in 2012, several vaccine candidates have been developed and tested. While no licensed MERS-CoV vaccines are currently available, these efforts have significantly advanced the understanding of coronavirus immunology, laying groundwork that also informed COVID-19 vaccine development.

The WHO R&D Blueprint for MERS-CoV prioritizes three vaccine types: (1) a dromedary camel vaccine to prevent zoonotic transmission, (2) a human vaccine for long-term protection of those at high exposure risk, and (3) a human vaccine for reactive use in outbreak settings [28]. Current MERS-CoV vaccines are in early development. All three candidates in clinical development, have been tested in Phase I clinical trials, target the MERS-CoV spike protein, which is key to viral entry [40]. These vaccine candidates [41] utilize the ChAdOx1 platform [42,43], which have been trialed in Saudi Arabia and the UK, Modified Vaccinia Ankara (MVA) vectors 44, and the DNA platform [40]. All candidates showed promising safety profiles and generated neutralizing antibodies. The sporadic nature of MERS outbreaks presents a unique challenge for vaccine development, as it limits the feasibility of large-scale clinical trials and necessitate the creation of both human and animal vaccines to prevent zoonotic transmission. Additionally, ensuring that vaccines provide long-lasting immunity without requiring booster doses remains an area of ongoing research. Despite these challenges, there is optimism that MERS-CoV vaccine development will benefit from lessons learned during the COVID-19 pandemic, particularly in terms of rapid development and scalable production [45].

IV. Best Practices and Lessons Learned from GCC Countries Efforts

1.Governance

Legislative mandates to respond to communicable diseases play a critical role in shaping public health responses to MERS. All Gulf Cooperation Council Member States (GCC MS) have demonstrated legislative readiness to manage and mitigate the risks associated with MERS. Following its emergence, MERS was integrated into the broader Acute Respiratory Infection (ARI) surveillance systems across GCC countries, operating within the framework of indicator-based surveillance for communicable diseases. Consequently, MERS has been designated as a notifiable disease, requiring mandatory reporting within 24 hours. This ensures timely reporting within 24 hours. This ensures timely reporting, enabling immediate public health interventions and reducing the risk of outbreaks. In addition, MERS testing was included in (SARI) Severe Acute Respiratory Infections in UAE as part of routine surveillance system.

Specific frameworks and policies have been established to respond to MER-CoV cases and mitigate associated

risks. National guidelines for managing MERS are developed and continuously updated by public health and infectious disease experts ensuring an adaptive governance approach. These guidelines include protocols for investigation, quarantine, surveillance, and management policies, at both the community and healthcare levels. For instance, the UAE has implemented a robust governance structure supported by the 2014 Communicable Disease Law, ministerial decrees, and a comprehensive manual for managing animal cases. Federal Law No. 8 of 2013 clearly mandates preventive and response measures, ensuring adherence to international standards for managing notifiable zoonotic diseases like MERS.

Being a zoonotic disease, MERS has enforced the implementation of the One Health approach to contain the virus. MERS has enforced multisectoral coordination in addressing health threats at the human-animal-ecosystem interface. The Ministries of Health, which is concerned with human health, with the Ministries of Water Environment and Agriculture, which concern with animal and environmental health are key stakeholders in this framework. This cooperation is formalized through the establishment of One Health national committees. These committees provide a legal framework and facilitate the implementation of zoonotic diseases prevention and control measures. By engaging relevant stakeholders, they support the development, implementation, and application of the national action plans. In UAE, integrated surveillance between animal and human was activated where animal sector was informed about every human case to initiate investigations of animal exposure and continued screening for MERS-CoV was conducted in camels and positive tests were reported to Ministry of Health for further investigation and active case finding in close contacts.

Sustainable funding specific to MERS management has been recognized as essential for maintaining surveillance, prevention, and control measures aligned with the One Health approach. In countries like Oman and Kuwait, the integration of MERS-CoV within the existing surveillance infrastructure, as part of ARI, and notifiable communicable diseases ensure efficient resource allocation for incidents response 46. However, funding structures for MERS-CoV programs vary across the GCC MS. In Saudi Arabia, MERS-CoV response is supported through sectoral annual budgets based on the recommendations from multisectoral committees, indicating some level of sustainability.

In some countries, such as Qatar, a One Health Strategic Framework has been established to enhance multisectoral coordination in the preparedness and response for future emerging and re-emerging zoonotic diseases 47. Once endorsed, the framework will establish sustainable funding mechanisms for related initiatives, including those targeting MERS.

Key Takeaway for Emergency Preparedness on Governance

Legislative Readiness: Ensuring the existence and flexibility of comprehensive frameworks for communicable diseases, with the focus on immediate reporting, timely sharing of information and data, containment, and management requirements for notifiable diseases are crucial for triggering timely public health interventions.

Integrated Surveillance Systems: Leverage, maintain and upscale surveillance systems such as ARI to ensure that emerging and re-emerging infectious diseases can be captured and later integrated. This will ensure efficient utilization of allocated resources for optimized preparedness and response.

Adaptive Guidelines and Protocols: Develop and regularly update national guidelines for the management of zoonotic diseases. This is particularly important when the chain of infection, treatment and prevention are not fully defined, which may impact the protocols for investigation, quarantine, and isolation at both community and healthcare levels. Also, regularly reviewing and updating the guidelines will reflect the latest scientific evidence and innovation such as new treatments or vaccines, to improve responses.

Sustainable Funding Mechanisms: Prioritize the establishment of sustainable funding mechanisms to support ongoing surveillance, prevention, and control efforts for zoonotic diseases. This will ensure resources are available during emergencies.

One Health Approach: Strengthen multisectoral coordination across human, animal, and environmental health sectors to effectively address threats by emerging and re-emerging zoonotic diseases. Strengthening may be achieved by the formalization of strategic frameworks and the formation of One Health national committees to ensure comprehensive planning and response. This will manage the cross-sector collaboration and defining the roles between stakeholders during preparedness stages and during crises.

2.Plans and Policies

Throughout the GCC MS, preparedness and response strategies for MERS have been systematically integrated into existing national emergency and communicable disease plans. These agile national plans are continuously updated to provide structured responses to public health threats, including emerging infectious diseases like MERS and re-emerging diseases.

Supportive policies have been vital in facilitating cross-sectoral coordination, ensuring a smooth and effective response to MERS. For instance, the national guidelines for the notification of communicable diseases in all of the GCC MS facilitate cross-sectoral reporting for MERS and support communication regarding the implementation of relevant preventive measures. Furthermore, the coordination of One Health national committees has streamlined collaboration among health authorities, agricultural, and environmental agencies, formalizing alignment to respond to or prevent the spread of MERS and other emerging or re-emerging zoonotic diseases.

Zoonotic disease prioritization exercise conducted in Saudi Arabia and Qatar identified MERS as a national priority. This has also aligned with input provided from all of GCC MS, which collectively recognize MERS as a priority disease. Consequently, given its public health significance and relevance to the GCC region, GCC MS have developed more detailed policies and guidelines in response to MERS, ensuring that surveillance, testing, and quarantine protocols are robust, effective, and tailored to local contexts. For example, tailoring policies that enforce serological and molecular surveys of camels participating in races and festivals. Risk assessment guidelines for contact tracing, quarantine, surveillance, incident reporting, and case management have become more specialized for MERS, enabling early detection and immediate containment of outbreaks. This approach has strengthened the preparedness of all One Health stakeholders across the GCC MS to respond effectively to MERS. The performance of these national plans, combined with existing and tailored policies and guidelines, has demonstrated success in Kuwait for example, in managing MERS outbreaks through the implementation of robust preventive measures.

Evaluating the technical functions of MERS programs is essential to optimize readiness and response capabilities. This evaluation is achieved through continuous monitoring of case identification, reporting, laboratory capabilities, and the timeliness of data sharing and response. Evaluation mechanisms encompass assessing the speed and accuracy of testing, the responsiveness of healthcare systems in detecting and isolating cases and analyzing epidemiological trends to guide and refine response strategies. Additionally, a bottom-up approach is employed by relying on technical feedback from frontline healthcare workers and technical staff to address unanticipated challenges. Periodic risk assessments are conducted to ensure that technical functions remain effective in the face of changing situations. This comprehensive monitoring (integrating both top-down and bottom-up approaches) ensures that MERS plans maintain high levels of readiness to respond to and manage new cases and potential transmissions.

Regular coordination meetings among the human health, agricultural, and environmental sectors responsible for animal health, along with international collaborations, are conducted to monitor disease outbreaks and share best practices. The inclusion of environmental and animal health agencies in surveillance and response activities underscores the importance of addressing MERS through the holistic One Health approach. For example, in Saudi Arabia surveillance activities, including periodic testing of camels for MERS-CoV, are conducted through the National Center for the Prevention & Control of Plants Pests & Animal Diseases (Weqaa) to monitor disease re-emergence, endemicity levels, and spread among camel populations. Additionally, Saudi Arabia held a simulation exercise in November 2024 on a MERS outbreak that utilized a multisectoral One Health approach. This workshop, involving the Ministry of Health, Public Health Authority (Weqaya), hospitals, and Weqaa, aimed to update and refine the MERS guidelines, clarifying and strengthening the coordination and roles of each sector in managing potential outbreaks.

Technical cross-sectoral evaluations are essential to ensure a high level of response readiness. These evaluations have led to the development of updated management protocols, improved diagnostic solutions, and enhanced One Health communication

strategies, and the allocation and distribution of shared resources, such as IPC materials and diagnostic tests. Effective collaborative efforts among One-Health agencies have improved response measures, including contact tracing in the case of human-to-human outbreaks and camel-to-human transmission incidents. Relying on previous preparedness experience such as the utilization of mobile laboratories in Hajj, the technical evaluations identified areas where additional resources are needed. These resources included mobile laboratories, mobile vet clinics, and satellite healthcare infrastructure, particularly during mass gathering events of cultural significance, such as camel festivals (Figure 5). As a result, GCC MS have enhanced their overall preparedness and adaptability to respond to MERS and other zoonotic diseases. Risk assessments and gap analyses were conducted, particularly in the veterinary sector, to identify deficiencies in response capabilities. For example, in Oman, risk assessments in animal health have helped to evaluate veterinary clinics and laboratory capacities, while Kuwait's General Authority for Agriculture and Fish Resources oversees the regulation of camel imports, ensuring animals are free of diseases like MERS before entering the country.

The principles and practices of the 4Cs (Communication, Coordination, Collaboration, and Capacity Building) serve as the foundation for MERS preparedness and response efforts. Effective and clear cross-sectoral communication ensures the dissemination of public health information, particularly to targeted high-risk individuals and communities. This includes public announcements, educational materials, press releases, and online platforms to inform relevant experts and stakeholders about current status updates, outbreaks, previous cases, and pertinent preventive actions. Coordination is facilitated through One Health national committees that are commissioned in some of the GCC MS, assuring that collaboration and a unified approach are followed across all government agencies responsible for human, animal, and environmental health.

Figure 5: *King Abdulaziz Camel Festival held in Saudi Arabia is the largest camel festival in the world*

Collaboration is maintained across all relevant sectors and stakeholders to ensure efficient resource allocation and distribution in response to zoonotic diseases, including MERS. As demonstrated in Qatar, UAE and Saudi Arabia, external collaborations with global health entities, such as the World Health Organization (WHO) and the U.S. Centers for Disease Control and Prevention (CDC), have provided additional expertise and resources to enhance response measures for emerging and re-emerging zoonotic diseases, including MERS. Capacity-building initiatives cover training across human health and animal health sectors, ensuring IPC training and resources are available, laboratory capabilities are enhanced, management plans are up to date, and satellite and mobile facilities are established to proactively respond to outbreaks through the One Health approach. These initiatives ensure that both human and animal health sectors are well-equipped with the knowledge and tools necessary to promptly manage cases and prevent potential outbreaks.

Inclusivity and equity are embedded in the national plans and policies for MERS response, ensuring that all sectors and segments of society are considered and included. By leveraging previous efforts in health equity, MERS plans assure equitable access to healthcare services for all, particularly for vulnerable and high-risk populations. All public health policies and initiatives are tailored to address the diverse needs of the diverse populations the GCC MS host and cater for.

Data analyses are employed to identify and address disparities in response plans, ensuring that public health interventions are widely applicable, targeted, inclusive, and effective. Regular evaluations of One Health policies ensure continuous improvement, aiming to achieve equitable outcomes for all sectors and individuals affected by zoonotic diseases

Key Takeaway for Emergency Preparedness on Plans and Policies

Agile Epidemic Preparedness Plans: Integrate preparedness for emerging and re-emerging zoonotic diseases into comprehensive national epidemic preparedness strategies. This will facilitate agile, adaptive, and prompt response mechanisms.

Continuous Evaluation: National plans, policies, and guidelines should undergo regular revisions, evaluations, and updates to reflect evolving threats, incorporate best practices and solutions, and address identified disparities. This will ensure that plans remain relevant in the face of emergFing and re-emerging diseases.

One Health Collaboration: Strengthen cross-sectoral collaboration through formalized and empowered mechanisms, such as One Health national committees. This will ensure an integrated response to zoonotic diseases.

Focus on the 4Cs: Ensure that preparedness policies and plans are developed on the principles of Communication, Coordination, Collaboration, and Capacity Building. Implementing the 4Cs will ensure effective, unified, and well-resourced responses to outbreaks.

Equity: Preparedness plans must prioritize inclusivity and equity, ensuring access to prevention and management for all segments of the population, particularly vulnerable and high-risk groups.

3.Health Workforce

Across the GCC MS, notable efforts have been made to enhance workforce capacities in response to zoonotic diseases, including MERS outbreaks. These initiatives focus on training, certifying, and retaining multisectoral personnel, improving their specialized skills, and increasing awareness of MERS among medical, animal health, public health, and other relevant stakeholders. Regular training programs and workshops have been conducted to improve the skills of response teams, particularly in areas such as surveillance, emergency response, communication, medical management, and IPC.

Structured and sustainable professional development training programs are delivered either in collaboration with international institutes (such as the FETP in Qatar and Oman, in partnership with EMPHNET and/or the U.S. CDC) or through local public health academies, such as those in Saudi Arabia including the Saudi FETP. Frequent training sessions for surveillance teams, active supervision visits, and simulation-based exercises have also contributed significantly to workforce preparedness. For instance, a specialized training program for healthcare professionals in ECMO was conducted in Saudi Arabia to equip medical staff with the necessary skills to manage critical MERS cases. In 2019, the Saudi FETP and Weqaya conducted two table-based simulation exercises on MERS one in Makkah just before Hajj and one in Riyadh, both were in collaboration with WHO EMRO. In Kuwait simulation exercises ensured that laboratories, human, and animal health sectors are adequately equipped to respond to emerging and re-emerging infectious diseases. Additionally, Oman integrates workforce development into its indicator-based surveillance system, which includes regular visits to sentinel sites, training for the healthcare workforce, and monitoring of admitted ICU patients.

The One Health approach is fundamental in shaping workforce training and development strategies for MERS preparedness in the region. This collaborative framework has led to the formation of joint response teams, emphasizing the importance of cross-sectoral coordination, and ensuring that all stakeholders are adequately trained and equipped to respond effectively to zoonotic disease outbreaks. As demonstrated in the simulation exercise that was held in Saudi Arabia in November 2024 on a MERS, by integrating the One Health principles into workforce training and development, shared skills can be cultivated, bridging the gap between sectors and fostering a unified approach to zoonotic disease preparedness. Notably, the implementation of scenario-based exercises, such as tabletop drills and large-scale multisectoral simulations of real-life outbreaks, enable response teams to practice and refine their strategies.

Multisectoral training programs for the workforce involved in zoonotic disease preparedness have proven to be attractive and effective. For example, in Saudi Arabia approximately 200 workers participated in a workshop co-delivered with the WHO on IPC for MERS, equipping them with essential skills to manage and contain zoonotic disease outbreaks. Similarly, during the One Health Week in Qatar in 2022, a training workshop convened joint risk assessment leads from EMRO-WHO, FAO, and WOAH, attracting 67 participants from 11 local institutions. This workshop focused on managing four zoonotic diseases, MERS, Avian Influenza, Rift Valley Fever, and Brucellosis, through the One Health framework, which holistically addresses human-animal-environment interfaces. Despite the implementation of various workforce training programs, the establishment of concrete metrics to assess their impact remains essential. These metrics will not only measure the reach of these initiatives but also evaluate their long-term impact, such as improvements in response times, reduced outbreak sizes, and enhanced cross-sectoral coordination.

The dedicated workforce training program has demonstrated effective outcomes and remarkable dedication among healthcare workers in their response to MERS (Figure 6). For example, in Saudi Arabia, the MERS critical cases response team in Jeddah has exemplified exceptional service by providing specialized care and transporting patients, often over long distances of up to 400 km, to ensure that critically ill individuals receive necessary treatment. This team operates 24/7 and has been pivotal in supporting designated MERS hospitals in remote areas. Another notable example comes from Prince Mohammed bin Abdulaziz Hospital, a designated referral center for MERS in Riyadh, where strict IPC measures have been implemented, resulting in zero nosocomial infections since 2015. The Saudi and Omani FETP graduates and trainees participated in the response of almost all the outbreaks in the countries. These success stories underscore the effectiveness of training programs and dedication of healthcare calibers, particularly in IPC, in controlling the spread of MERS within healthcare settings and beyond.

Key Takeaway for Emergency Preparedness on Healthcare Workforce

Figure 6: *Pictures of dedicated laboratory staff from Bahrain exemplifying the health workforce commitment to respond to MERS*

Continuous Workforce Training and Development: Regular, structured, and sustainable training programs, such as the FETP, specialized workshops, capacity-building initiatives, and retention strategies for trained healthcare workers and multisectoral teams, are essential for strengthening surveillance systems and maintaining readiness to respond to emerging and re-emerging zoonotic disease outbreaks.

Simulation-Based Training: Implement scenario-based exercises, including large-scale multisectoral drills, to prepare the workforce for real-life emergency scenarios. These exercises will facilitate skill exchange and bridge gaps between professionals across various sectors, fostering future collaboration and coordination.

International Collaborations: Leveraging partnerships with international organizations, such as WHO, WOAH, FAO and U.S. CDC can enhance training efforts by providing global expertise, knowledge exchange and best practices.

Effectiveness Evaluation: Monitor the impact of training on the healthcare workforce and multisectoral personnel to assess long-term effects on outbreak response capabilities.

Readiness: Having specialized frontline health workforce response teams on duty 24/7 covering a wide geographical area is crucial for rapid response to zoonotic diseases emergencies. It is critical to equip them with the necessary tools and skills to respond effectively and recognize their effort.

4. Surveillance

The surveillance systems implemented across the region for MERS rely on a combination of passive and active methods to effectively detect, control, and prevent outbreaks. MERS is classified as a "Category I" reportable disease, requiring immediate notification within 24 hours. Failure to report can lead to legal consequences, potentially affecting licensing and certification. Both passive and active surveillance activities are conducted across healthcare settings, animal health sectors, and public health institutions.

The use of electronic surveillance systems, such as the Health Electronic Surveillance Network (HESN) in Saudi Arabia, the Surveillance and Vaccine Electronic System in Qatar and a similar electronic system in Oman, enables real-time reporting, data analysis, and visualization. Guided by artificial intelligence and machine learning, these systems support rapid decision-making. They are instrumental in informing public health interventions, facilitating contact tracing, and guiding field investigations to prevent further transmission. Additionally, comprehensive situational reporting and contact tracing assessment are employed for each MERS case, detailing clinical status, symptoms, patient history, laboratory results, isolation measures, exposure risks, and contact tracing-related information. These reports help to identify, manage, and contain the routes of transmission, and prevent the further spread of outbreaks.

The One Health approach is deeply integrated into MERS-CoV surveillance systems across the region. Active surveillance activities include randomly, and in some instances systematically, screening camels for MERS-CoV, particularly in livestock markets and cultural events such as camel competitions in Saudi Arabia, where tens of thousands of camels go under health checkup including MERS-CoV testing before the owner obtains a permit into the competition, this is linked to a digital microchip identification as well as an electronic information system. Kuwait has also conducted regular molecular testing of camel samples (rt-PCR), which has led to the identification of infected camels, triggering stringent monitoring and surveillance in humans. Recently, rapid antigen detection test kits and IgG ELISA tests have been used for routine active surveillance of MERS-CoV in camel nasal swab samples. The animal health sector plays a critical role in identifying MERS-CoV transmission between humans and animals (Figure 7), aiding in the detection of animal cases and implementing stringent IPC measures. Multisectoral surveillance efforts collaborate in outbreak investigations, particularly when human cases are linked to animal exposure. Field personnel from both human and animal health authorities jointly conduct contact tracing and track animal sources, resulting in effective containment measures such as quarantine to mitigate further spread.

Figure 7: *Collecting nasal swabs from camels to screen for MERS-CoV in Oman, provided by the Oman One Health Technical Working Group Member.*

The evaluation of surveillance systems is conducted through well-defined indicators that assess their effectiveness, responsiveness, and turn-around-time in detecting and controlling outbreaks. One key indicator includes response time, which evaluates the timeliness of response from rapid response teams and healthcare facilities following suspected case detection. Reporting completeness is another key indicator, which measures the percentage of healthcare facilities submitting complete and timely reports; and laboratory confirmation rates, which measures the proportion of suspected cases confirmed through laboratory testing. MERS-CoV surveillance is also evaluated based on the quality and quantity of field investigations, contact tracing, and follow-up activities. These measures ensure that any potential cases are comprehensively addressed, and the information gathered through the through reporting systems are used to refine interventions. For example, the active surveillance conducted on camels and farm workers following the identification of the virus in the senior citizen in Qatar has led to the confirmation of camel link as an animal host along with other studies in Saudi Arabia.

The efficiency of MERS-CoV surveillance and outbreak response is supported by several factors that enhance outbreak detection, coordination, and response. The ability to quickly update existing surveillance protocols, such as the transition from SARI to SARI-Intensive Surveillance (SARI-IS) in Oman, has improved the detection of MERS-CoV and other emerging respiratory pathogens. This upgrade enabled the successful detection and containment of two MERS outbreaks in Sohar and Sur hospitals, preventing further spread in healthcare and community settings [48]. Additionally, improved multisectoral communication, particularly between human and animal health sectors, facilitates timely information sharing and coordinated responses, including the quarantine of infected animals and the implementation of field investigations and contact tracing. Engaging leaders within the animal-keeping community, such as camel owners, plays a significant role in facilitating access to farms and encouraging participation in surveillance efforts (Figure 8). This collaboration strengthens data collection and reinforces public health interventions.

Since Sep 2012 until June 2024, a total of 2613 MERS confirmed cases were identified and reported throughout the world with 943 fatalities. No new outbreaks, and two new fatalities were reported since the last update (6 June 2024) [17]. To assure surveillance activities are being conducted to the highest level recently the WHO has published a cross-sectional protocol of MERS in population who are occupationally at high risk of acquiring the infection due to their high exposure to camels. This standardized study can be applied at any time to estimates the seroprevalence, prevalence (current infection) and viral shedding, as well as the geographical extent of MERS infections, among occupationally exposed populations and their dromedary camels [49].

Figure 8: *Engaging with community leaders and camel owners can facilitate sample collections related to surveillance activities, provided the by Saudi Arabia One Health Technical Working Group Member.*

Key Takeaway for Emergency Preparedness on Surveillance

Integrated Surveillance: Surveillance systems should incorporate both passive and active approaches and capitalize on opportunities to integrate emerging pathogens into existing systems to ensure comprehensive monitoring and detection of potential outbreaks.

Timely Reporting: Prompt reporting notifiable zoonotic diseases within a specific time frame is essential for triggering rapid response.

Multisectoral Surveillance: Applying the One Health approach to MERS-CoV surveillance is vital for identifying transmission pathways and controlling outbreaks. Regular screening of known animal host followed by cross-sectoral reporting can facilitate early detection of zoonotic pathogens and prevent cross-species transmission to humans.

Multisectoral Response should be mobilized together to investigate outbreaks in the field. Their combined expertise helps ensure comprehensive investigations.

Community Engagement: Engaging local communities in surveillance efforts can enhance access to critical information, particularly in rural or high-risk areas.

Surveillance Evaluation: Surveillance system efficiency and effectiveness should be regularly evaluated using well-defined indicators to maintain effective case detection and outbreak management.

Technology Integration: Staying current with the latest diagnostic tools and technologies is essential for enhancing field surveillance activities and optimizing operational processes.

5. Clinical Case Management

Most GCC countries have developed or adopted effective clinical management guidelines for MERS, aligning with recommendations from the WHO and U.S. CDC. These guidelines are specifically designed to address the unique challenges posed by MERS and emphasize the critical steps of conducting surveillance activities to rapidly identify cases, followed by laboratory diagnosis, isolation, and IPC measures to prevent further transmission. Clinical management protocols generally include detailed guidance on symptom recognition, patient isolation, follow-up procedures, stringent IPC measures, and the management of hospitalized patients. These protocols have significantly contributed to a reduction in incidence, mortality, and complication rates.

The structured implementation of national guidelines has been pivotal in reducing MERS-CoV transmission. National health authorities have developed systems for rapid case notification and investigation, ensuring prompt isolation and management of suspected cases. For example, Saudi Arabia published its updated national guidelines for healthcare professionals in 2018 [50], fostering a coordinated approach that led to reduced mortality rates and clinical complications associated with MERS. These guidelines, which include an algorithm for identifying and managing suspected cases, provide a comprehensive framework for case identification, reporting through HESN, contact tracing, and case management. They clearly define isolation procedures, IPC measures, and clinical care protocols for hospitalized patients, including the use of advanced interventions such as bilevel positive airway pressure (BiPAP) or ECMO when necessary. Given the absence of targeted antiviral therapies or vaccines for MERS, supportive care remains the only recommended treatment. The guidelines also outline stringent recommendations for the use of personal protective equipment (PPE), mask-fit testing for healthcare workers, and restrictions on aerosol-generating procedures for suspected or confirmed cases, to minimize the risk of virus transmission in healthcare settings. Furthermore, they offer detailed protocols for specific scenarios, including managing hospital-based MERS outbreaks, transporting MERS patients, and handling the bodies of deceased patients to mitigate any associated risks and eliminate uncertainties.

Countries across the Gulf region have also introduced innovative clinical management practices, informed by past experiences and tailored to the unique challenges posed by MERS outbreaks. In Oman, a national triage system was introduced to manage patients with respiratory symptoms presenting at emergency rooms and healthcare centers. This system, coupled with robust IPC protocols, enabled any hospital to manage confirmed MERS cases while preventing transmission to other patients and healthcare workers.

Key Takeaway for Emergency Preparedness on Clinical Case Management

National Clinical Guidelines: Develop, constantly update and adhere to clear, evidence-based national clinical guidelines, that align with international standards or/and recommendations, which can lead to consistent and effective management.

Clinical Pathways: Clinical management protocols must be adaptable, allowing for rapid updates as new information, management procedures and treatments become available.

Supportive Care: For emerging zoonotic diseases without definitive treatments, supportive care resources must be ensured such as ICU capacity, BiPAP and ECMO.

Rapid Diagnosis and Immediate Isolation: Rapid diagnosis, triaging and prompt isolation of cases are crucial for preventing the zoonotic disease spread

Prioritization of High-Risk Cases: When recourses are constrained, triage systems must be in place to prioritize high-risk cases, ensuring critical patients receive immediate care.

Stringent IPC: Strict IPC measures are critical to preventing community and nosocomial transmission. This includes the proper use of tested PPE.

One Health Approach in Case Management: Collaboration between human health, animal health, and environmental sectors ensures that cases linked to animal contact are quickly identified and quarantined to prevent further transmission.

Research and Development: Innovate or/and support R&D efforts into novel therapeutics and vaccines for emerging and re-emerging infectious diseases, which are necessary to improve the long-term clinical outcomes.

6.Laboratory Diagnostics

Across the region, GCC MS have made significant progress in establishing and scaling up MERS-CoV diagnostics, primarily through the widespread use of molecular assays, serological tests, and, in some instances, genomic sequencing. MERS-CoV testing is now part of routine clinical laboratory diagnostics and integrated into national public health lab-based surveillance systems. All of the practices in the GCC MS align with the WHO recommendation for laboratory testing for MERS-CoV [51]. Weqaa in Saudi Arabia and Abu Dhabi Agriculture and Food Safety Authority (ADAFSA) in the UAE have played pivotal roles in conducting serological and molecular surveys of camels, particularly those in contact with confirmed human cases and those participating in races and festivals. Notably, the UAE's advanced scientific infrastructure in the animal health sector has enabled it to have two WOAH recognized reference laboratories, one internationally recognized as WOAH reference laboratory for MERS-CoV and the other one is recognized as WOAH collaborating center for camel diseases. Similarly, the General Authority for Livestock in Kuwait has been instrumental in supporting laboratory diagnostics for animals by collaborating with health sectors and utilizing molecular and rapid antigen detection tests to screen camels for MERS-CoV, as well as serological tests (IFA techniques) for camels and herders.

Most countries have established comprehensive testing protocols with unique algorithms (Figures 9 and 10), focusing on the rapid detection and confirmation of MERS cases in human and animal health sectors. In Saudi Arabia, all SARI and ILI samples that test negative for influenza are screened for MERS-CoV using RT-PCR. Bahrain employs a structured algorithm that includes the early collection of respiratory specimens in the symptomatic phase, with retesting conducted in cases of high clinical suspicion. In Oman, MERS-CoV testing is carried out on any suspected case, including patients presenting with SARI, and 10% of overall respiratory samples received in the laboratory are screened. Molecular screening is also widely used to screen camels for MERS-CoV. Oman and Saudi Arabia have carried out extensive surveillance studies on camels, primely in the northern provinces (Figure 11). In 2021 alone, 1,400 nasal swab samples were collected from dromedary camels across different governorates in Oman, all of which tested negative for MERS-CoV. Seroprevalence surveys, especially in camels, are also common across GCC MS. During the 2013 outbreak, Qatar applied a screening algorithm based on international guidelines, which helped in prioritizing suspected cases and reducing unnecessary testing. This protocol reduced the number of tests from 12,563 to 514, identifying seven positive cases without any cross-infection. The system also improved emergency department efficiency, reducing the turnaround time for PCR results from three days to one day also resulting in streamlining patient management and isolation processes. In Saudi Arabia, serological surveys of camels have been conducted since 2014, with plans to expand these efforts in 2025. However, human seroprevalence studies are underdeveloped in several countries, and expanding these efforts could provide valuable insights into immunity levels and the broader spread of MERS-CoV.

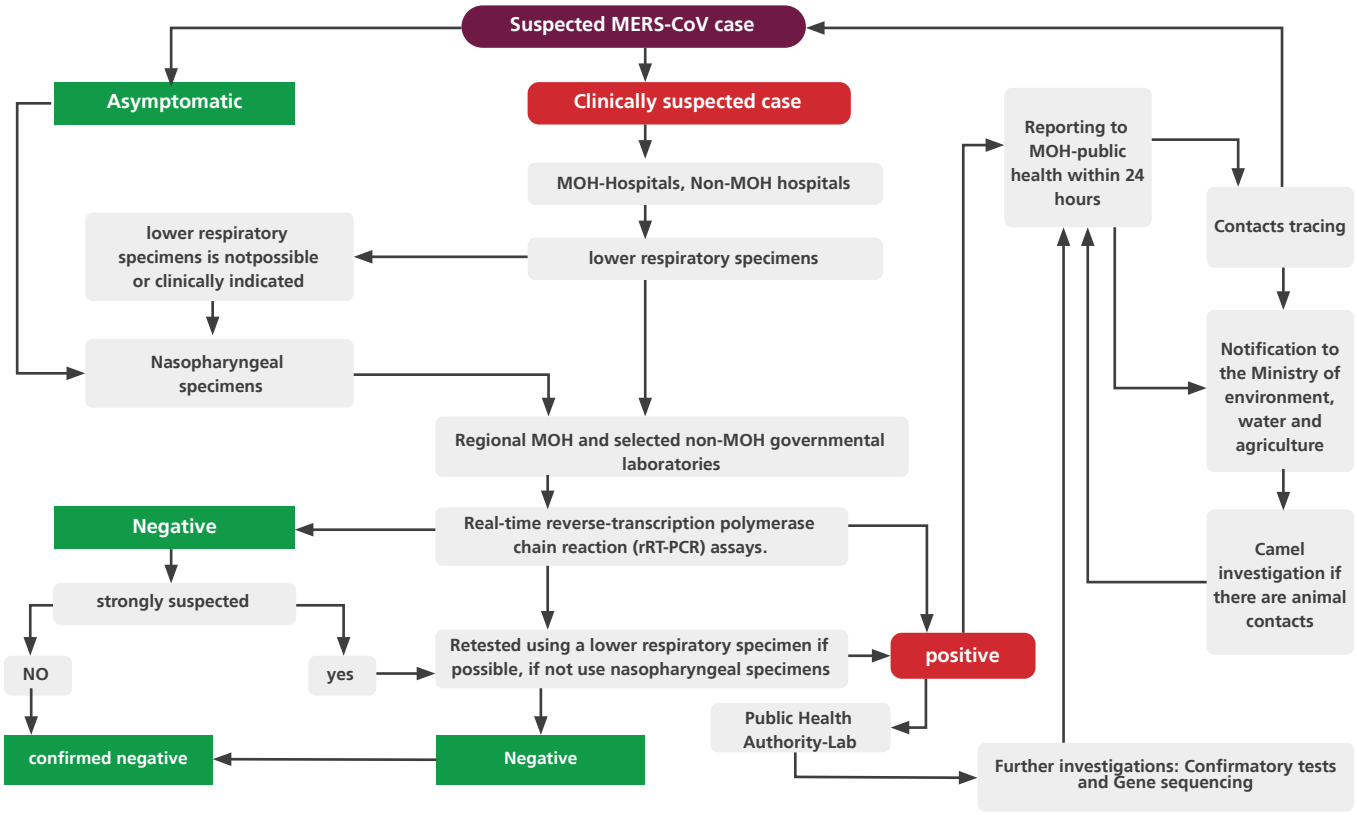


Figure 9: *Example for the testing algorithm followed by the public health personnel in Saudi Arabia*

Algorithm for testing cases under investigation for MERS-Cey by RT-PCR

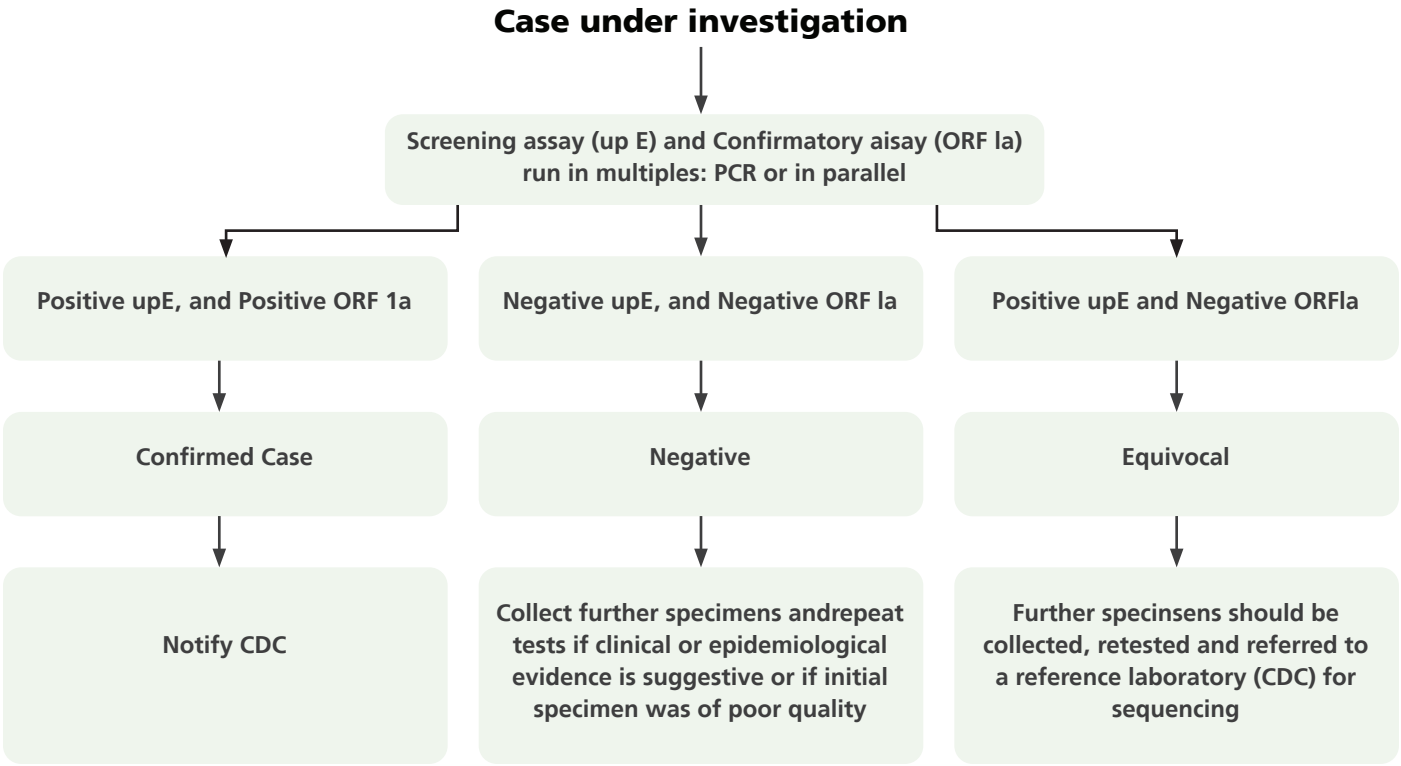


Figure 10: *Example for the testing algorithm followed by the public health personnel in Bahrain.*

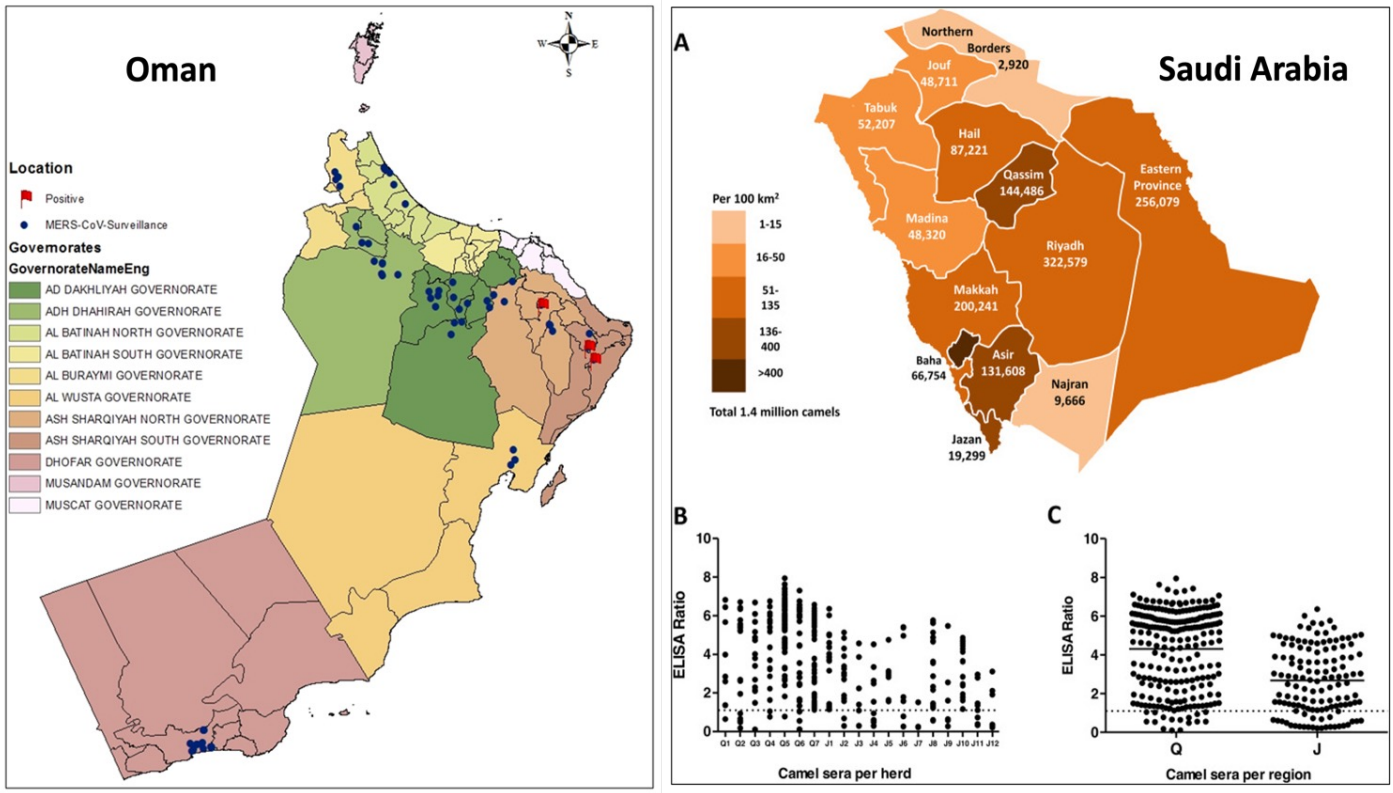


Figure 11: *Locations of the sampled camels and the positive results in camel surveillance for MERS-CoV in Oman, 2013, adopted from the Animal Health Research Center in Oman; and in Saudi Arabia, 2019 52.*

Efficient diagnostic systems are characterized by high testing volumes, quick turnaround times, and the ability to manage surge capacity during outbreaks. Laboratories across the region have emphasized rapid turnaround times to enhance MERS response efficiency. All GCC MS have the capacity to report human testing results within 24 hours, while Oman can provide results for animal samples within 48 hours. These fast turnaround times enable swift public health responses, ensuring timely case detection, contact tracing, and isolation of confirmed cases. Managing surge capacity is another critical aspect of laboratory diagnostics. Countries have adopted various strategies to handle increased testing demand during outbreaks. For example, Saudi Arabia has implemented flexible procurement processes to ensure diagnostic supplies are available during peak periods. In Kuwait, an emergency laboratory team operates on a 24/7 basis to manage high testing volumes during outbreaks.

Quality assurance measures are a key focus across laboratories in the region. Adherence to SOPs and proficiency testing ensures the reliability of diagnostic results. External quality validation is another layer applied to maintain high standards. For instance, ADAFSA's laboratory in the UAE has attained several ISO accreditations for Quality Management Systems, Environmental Management Systems, and Occupational Health and Safety Management Systems, among others. As a result, it has been recognized as a WOAH Collaborating Center for Camel Diseases, a WOAH Collaborating Center for Quality Management Systems, the national reference lab for MERS-CoV, and the national reference lab for Crimean Congo Hemorrhagic Fever (CCHF). In Qatar, the national laboratory operates under CAP accreditation, ensuring alignment with global best practices in diagnostics. In Kuwait, Laboratory staff completed accredited training programs in collaboration with the WHO. They also follow strict quality management system protocols.

Genomic sequencing and bioinformatics have been implemented in some countries to track MERS-CoV evolution and transmission dynamics, enhancing outbreak response strategies (Figure 12). PHL-PHA in Saudi Arabia has established a viral genomic sequencing system for MERS-CoV, providing insights into the virus's genetic changes over time. Similarly, ADAFSA in the UAE plays a leading role in genomic sequencing, leveraging cutting-edge systems and depositing MERS-CoV sequences into public genomic databases such as GISAID, promoting global collaboration in epidemiological surveillance. Samples have also been shared with academic institutions for research purposes. Expanding genomic sequencing capabilities across GCC MS remains a key area for future investment and capacity building, particularly to track viral changes that could influence outbreak dynamics.

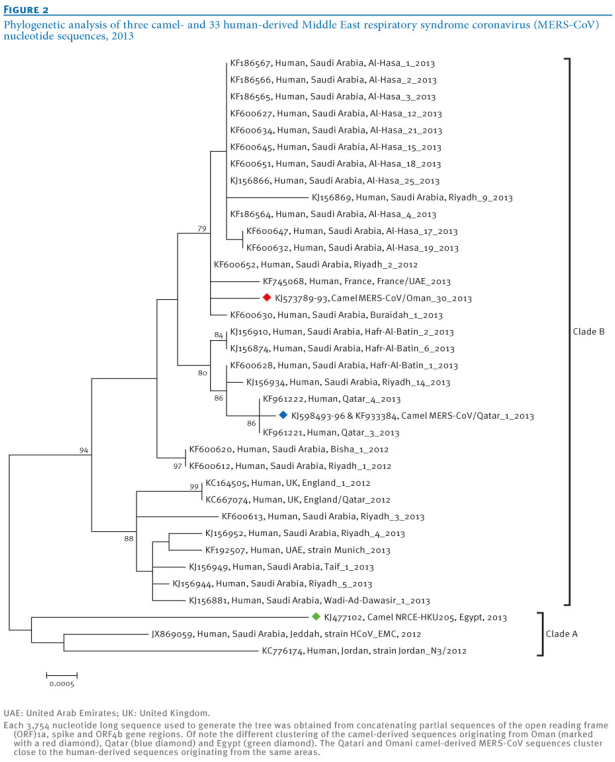


Figure 12: *Phylogenetic analysis of camel and human isolates, an exercise that has been conducted and published by many researchers in GCC. Example is shown for three camel and 33-human-drived MERS-COV nucleotide sequences in 2013*

Enhancing laboratory capacities is crucial for maintaining preparedness to effectively respond to outbreaks. GCC MS are investing in upgrading laboratory infrastructure, attracting and retaining skilled personnel, and improving logistical systems to ensure the efficient transportation and handling of specimens. Continuous education and training programs are being implemented to ensure that laboratory staff are kept up to date on the latest diagnostic techniques and safety protocols, enhancing testing throughput and biosafety measures. Capacity building also being reflected on updating diagnostic techniques and biosafety protocols to assure readiness. For example, UAE, in collaboration with Hong Kong University, has developed a rapid immunochromatographic test (ICT) for MERS-CoV antigen detection in dromedary camels, which has been adopted by WOAH as a rapid/field test for MERS-CoV. Through UAE efforts, WOAH has included the MERS-CoV immunochromatographic test (ICT) as an acceptable method for screening camels for MERS-CoV 53. To ensure fit for purpose use of rapid tests, UAE has also developed a testing algorithm for camel as shown in figure 13. Kuwait Central Public Health Laboratories (CPHL) issued a summary guidance in case of identification of suspected cases (Figure 14) with clear instructions related to sample transportation (guidelines and protocols).

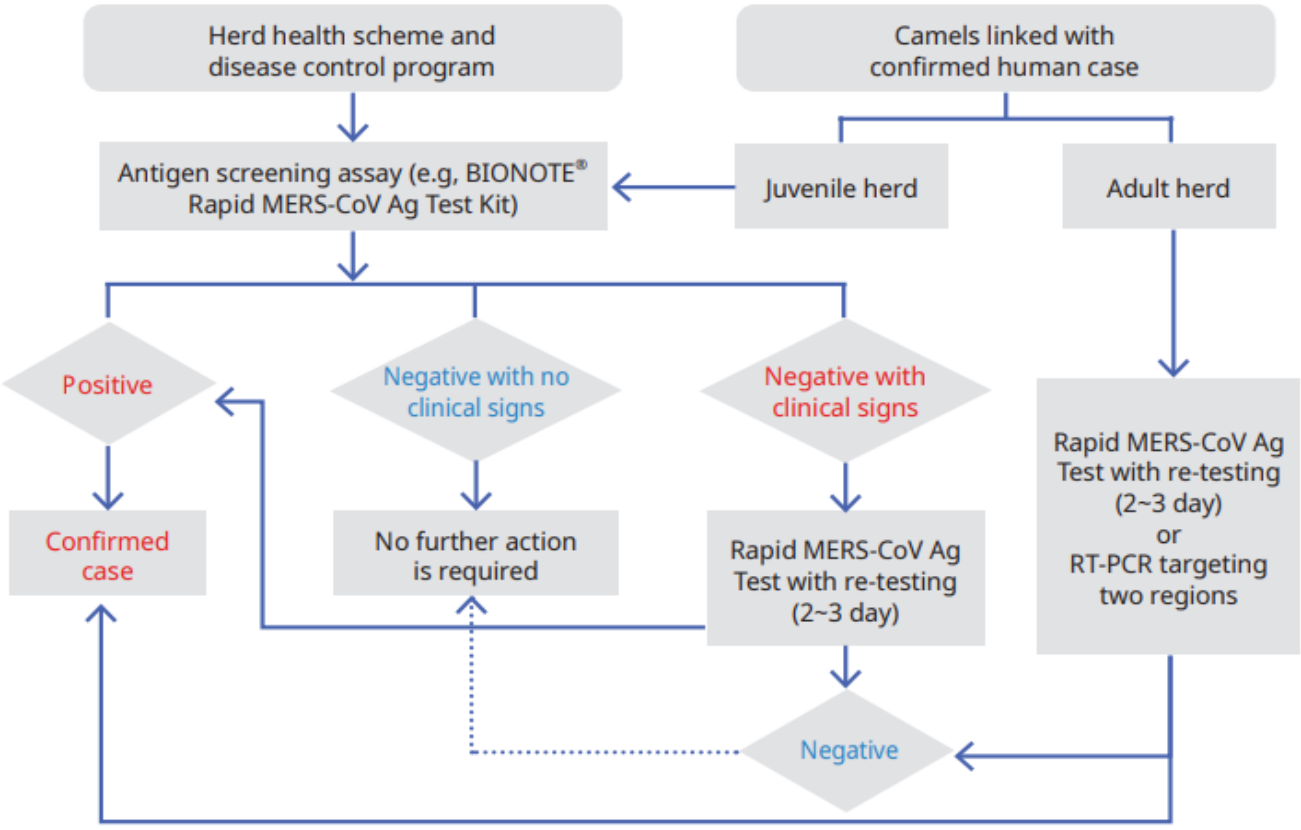


Figure 13: *Example for the testing algorithm for camels in United Arab Emirates*

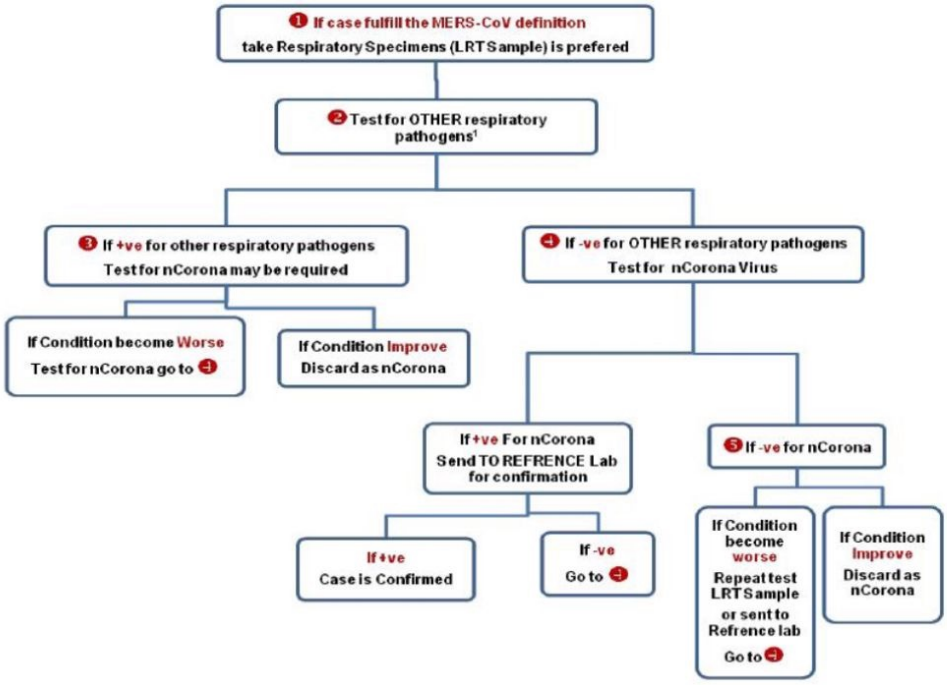


Figure 14: MERS-CoV Testing Algorithm at Central Public Health Lab in Kuwait

Key Takeaway for Emergency Preparedness on Laboratory Diagnostic

Testing Integration: Laboratory diagnostics for emerging and re-emerging zoonotic diseases (MERS in this case) should be integrated into testing algorithms across human and animal health sectors. This enables continuous surveillance and early detection, especially for unknown pathogens using routine testing.

Real-Time Surveillance: Integrating laboratory results into national surveillance systems is crucial in enabling rapid detection, reporting, and response.

Seroprevalence Studies: Conduct large seroprevalence studies in human and animal populations is critical for understanding immunity levels, assessing disease magnitude and tracking the spread of zoonotic diseases to inform public health strategies. These studies should be systematic, sustainable, and nation-wide, beyond research serological studies. Frequency of the studies can vary based on the risk assessments.

Technological Advancements: Ongoing investment in cutting-edge diagnostic tools, and the ability to adapt to new technologies, are crucial for enhancing early detection and response capabilities during outbreaks.

Genomic Sequencing: Genomic sequencing and bioinformatics should become standard practices for tracking the spread and evolution of pathogens. It is also important to share genomic data on international levels through public genomic databases for global collaboration and monitoring [54].

Surge Capacity Planning: Laboratories must have optimized contingency plans to manage increased testing volumes during outbreaks. This includes ensuring adequate staffing, expanding operating hours, and securing diagnostic supplies.

Capacity Building: Continuous capacity building for laboratory personnel is essential. Regular training on new diagnostic techniques, protocols, and equipment should be assured to maintain operational readiness.

Quality Assurance: Implement stringent quality assurance measures and participate in proficiency testing programs to accuracy and reliability of diagnostic results.

7. Healthcare Facilities and IPC

The GCC MS, have made significant strides in developing and implementing enhanced IPC measures and strategies in response to MERS-CoV outbreaks. These efforts demonstrate a strong commitment to prevent MERS-CoV transmission, protecting healthcare workers, and ensuring that healthcare systems remain shielded during outbreaks. Across the region, countries have employed innovative strategies, established rigorous protocols, and leveraged cross-sectoral and regional collaborations to enhance IPC efforts. These innovations range from updated national and GCC-wide IPC guidelines, to structural modifications in healthcare facilities, tailored to respond to the unique risks posed by MERS-CoV.

GCC MS have adopted multiple strategies to mitigate the risk of nosocomial transmission within healthcare settings. For example, in Oman, multi-machines were installed in isolation rooms to convert normal ventilation to negative pressure rooms equipped with high efficiency particulate air (HEPA) filters, significantly enhancing containment capabilities. Saudi Arabia developed a very comprehensive and evidence-based IPC guideline specifically for MERS, supported by regular audits to ensure compliance. Auditing teams supervised by hospital highest management play a critical role in ensuring that healthcare workers adhere to the IPC protocols, including the correct use of PPE. In the UAE, strict protocols for handling patients with ILI were established, including dedicated waiting areas, use of PPE, and separation of patients by at least one meter in waiting rooms. Healthcare workers handling suspected cases are mandated to follow a stringent protocol involving the use of N95 masks, gowns, gloves, and eye protection, especially during aerosol-generating procedures. In Kuwait, all healthcare facilities were equipped with adequately ventilated dedicated waiting areas and clinical triage for early identification of all patients with ARIs. Saudi Arabia and Qatar took a unified approach by implementing a triage process across all healthcare facilities. This approach not only reduces the risk of transmission within healthcare facilities but also ensures that MERS cases are identified early, isolated and patients receive timely care. Oman's national IPC guidelines include comprehensive measures such as cohorting patients, enhancing cleaning, and staff training on risk assessments for contact screening. Furthermore, educational and awareness programs targeting healthcare workers have been expanded, including the implementation of drills and tabletop exercises to emphasize the importance of compliance with IPC measures. These strategies highlight the regional emphasis on early detection and containment to mitigate the risk of nosocomial transmission at healthcare settings.

The safety and well-being of healthcare workers have been a primary focus during MERS outbreaks, with GCC MS taking proactive steps to protect healthcare staff. This is being assured through a combination of enhanced training, adherence to IPC protocols, and adequate supply of PPE. For example, the Saudi IPC guideline for MERS ensures the importance of IPC compliance and emphasizes on the importance of adhering to regulations. The supply chain was optimized across the region to ensure an adequate supply of PPE, powered air-purifying respirator (PAPR) and HEPA filters are provided to all health care facilities. Support systems for healthcare workers have included tailored health programs, such as specialized employee clinics that provide immediate care and management for staff exposed to MERS cases before returning to their duties. Healthcare workers have also benefited from standardized training and education programs on IPC measures and equipment, supplemented by drills to assure

protocol effectiveness. Training programs, like Qatar's Certified Professional Infection Control (CPIC) course, targeted IPC staff in healthcare facilities, ensuring they had the necessary skills and knowledge to manage MERS cases. As a result, Qatar has never faced a nosocomial infection caused by MERS-CoV, to date. In Saudi Arabia, major hospitals such as those of national guards mandated an IPC refreshing training for all healthcare workers. In Kuwait, a comprehensive approach to infection prevention and control (IPC) was implemented across healthcare facilities, including surgical, dental, and critical care. This included training on isolation precautions, PPE usage, waste management, and disinfection practices, complemented by regular audits and feedback to enhance compliance. Clear communication channels with healthcare authorities ensured continuous improvement and effective guidance.

Non-health sectors have also played a pivotal role in IPC efforts by providing financial, logistical, and technical assistance to addressing structural and resources needed to address challenges posed by MERS-CoV. Weqaa Center in Saudi Arabia, implemented IPC procedures in veterinary labs and clinics, ensuring that field and laboratory staff handling animal samples were equipped with appropriate PPE and trained on proper IPC practices. The establishment of Weqaa as a public health arm of the Ministry of Agriculture is in itself a national move towards better IPC. The negative pressure devices in healthcare facilities in Oman, were financed by the non-health sectors. In Qatar, the supply chain was strengthened to ensure optimized procurement of PPE and HEPA filters. Additionally, the environmental cleaning of healthcare and public spaces was enhanced through regular audits, training of staff, and clear guidelines for cleaning and disinfection practices.

Key Takeaway for Emergency Preparedness on Healthcare Facilities and IPC

Tailored IPC Guidelines: National IPC guidelines must be designed and regularly updated based on evolving scientific evidence to ensure that healthcare workers and facilities are prepared to handle the specific emerging infectious diseases.

Enhanced IPC Capabilities: Healthcare facilities should invest in advancing infrastructure such as negative pressure rooms with HEPA filters to prevent nosocomial infections and manage future outbreaks effectively.

PPE Availability and Training: Ensure that healthcare workers have sufficient access to adequate PPE, with regular training.

Triaging: Implement triage systems for rapid case identification, isolation, and management, which can help in reducing the risk of transmission within healthcare settings.

Healthcare Worker Safety: Assure the safety and well-being of healthcare workers through targeted safety programs, including PPE supplies and immediate access to healthcare services.

Multisectoral Collaboration: Engage non-health sectors in IPC efforts throughout the One Health multisector and also adequate funding and logistical support are provided.

8. Research and Development (R&D)

Research and development (R&D) effort in the GCC MS have been pivotal in the effective management and understanding of MERS outbreaks. GCC MS, particularly those where MERS has had significant impacts, have leveraged scientific research to better understand the virus, its transmission dynamics, and the role the animals vector plays in transmitting the virus. This has contributed to enrich the global knowledge about MERS, while practicing, research and developing One Health strategies and zoonotic disease management. The R&D effort also included preventative measures such as vaccine research. For example, Saudi Arabia's King Abdullah International Medical Research Center (KAIMRC) has contributed to the R&D of MERS-CoV vaccine in collaboration with international institutes, reflecting a leadership commitment and demonstrating the capabilities in the GCC MS to address zoonotic diseases challenges. The only therapeutic clinical trial published so far, the MIRACLE trial, was conducted across 16 hospitals in Saudi Arabia [55]. Similarly, a long list of universities and research centers, especially in Saudi Arabia and Qatar, have conducted essential scientific research studies in collaboration with renowned international institutes.

One of the main discoveries that resulted from MERS-CoV R&D efforts was the identification of camels as the main animal host, which was also followed by identifying the circulation of specific clades within the camel population. Several similar research projects were carried out across the GCC MS to confirm the connection between camels and human infections through whole genome sequencing. This discovery has been the cornerstone in the One Health approach to manage MERS outbreaks. As a result of these findings were the development of One Health public health policies, such surveillance of camel populations and camel owners and handlers. These measures illustrate how GCC-based research has directly applied to improve response efforts of the zoonotic disease, a lesson that can be applied to other diseases.

Several studies from the GCC MS have enhanced the global knowledge about the burden of MERS, through prevalence studies. These studies were conducted on locally bred and imported camels. Also, seroprevalence studies were conducted on camels as well as healthy individuals. These studies are vital to understand the dissemination and impact of MERS on a population level. These studies have also helped to evaluate the magnitude of asymptomatic and mild infections among the diverse geographical distribution and population segments at the GCC MS. Building on seroprevalence studies can also guide innovations for interventions. For example, ongoing research projects at Qatar are focusing on characterizing the immune response in individuals infected with MERS-CoV and vaccinated against SARS-CoV-2. The main goal of these projects is to isolate mAb from these individuals. Other collaborative projects also aim to study nanobodies against MERS-CoV.

To capture all the accomplished R&D effort, the Gulf CDC has carried out independent systemic review summarizing MERS-CoV research outputs from the GCC MS. The outcome of this systematic review will be shared with the GCC MS and published as a separate document. In short, a pubmed search in title/abstract revealed >2500 articles published on MERS-CoV, those affiliated with any of the six GCC countries were >400. Of those, the majority of the studies were descriptive epidemiological studies to investigate the existence and dissimilation of MERS-CoV or its exposure among various population groups using immunological and molecular-based assays or in some studies whole genomic comparative analyses. Translational research studies on diagnostic tests have empowered the stakeholders with the tools to better diagnose MERS. Several landmark studies have demonstrated the efficacy of vaccines candidate or drugs to control the viral load and its spread among human or animals as mentioned above. The majority of the R&D efforts were addressed in 31 (7%) systematic review articles. In terms of the study locations, Saudi-based researchers have contributed to 288 (67%) of the literatures, followed by UAE with 16 (3.7%) studies and Qatar with 15 (3.5%) studies.

Key Takeaway for Emergency Preparedness on Research and Development

Significance of R&D to Guide Outbreak Response: Epidemiological studies are vital in identifying vectors, understanding transmission dynamics, and risk factors of emerging and re-emerging zoonotic diseases.

Research Translation to Practice: Tailored outbreak response and preparedness require agile and responsive policy development systems that incorporate research findings to interventional guidelines.

Multisectoral Research Collaboration: The One Health approach should be the guiding principle in zoonotic diseases research.

Capitalizing on Research Successes: Leverage the existing capabilities, talent and collaborations in diagnostic and vaccine development to address challenges caused by other emerging and re-emerging zoonotic diseases.

Utilization of Global Networks: Collaborate with international research institutions to facilitate knowledge sharing, building capabilities and expedite discoveries.

Capacity Building: Local R&D capabilities can be vital in addressing pressing questions of public health importance.

Publications of Research Output: Maintain publishing of research endeavor to enrich the global knowledge of zoonotic diseases, particularly endemic diseases to the region.

9. Supply Chain Management

A resilient and responsive supply chain ensures the delivery of vital equipment such as respirators, diagnostics kits, and PPE, enabling rapid detection, treatment, and containment of outbreaks. The supply chain management of resources used with MERS response across the GCC MS has been a critical component in ensuring the availability of essential supplies. These supply chain strategies are maintained efficiently and continue supply not only in the health sector, but also in the broader animal sectors. For example, in Saudi Arabia, a dedicated supply chain and inventory platform are used to monitor and manage the daily needs of supplies at the health facilities through the Command Centre and situation rooms to track the used and needed resources on at real-time bases. The system is supported by flexible procurement processes to ensure that all various supplies are always available, particularly during peak periods and large outbreaks. This system is governed by contingency plans that address any shortages through a well-coordinated supply exchange between regions and support from high-level committees. Nowadays, the National Unified Procurement Company (NUPCO) in Saudi Arabia plays a pivotal role in governing medical supply procurement, improving efficiency, and supporting inter-regional supply exchanges in Saudi Arabia when needed. Similarly, in the veterinary sector, supply chain management ensures the availability of diagnostic kits, sample collection consumables, and PPE to support the integrated human-animal health response.

Technological innovations such as electronic supply management systems have also been instrumental in supporting real-time resource monitoring. For example, the WEQAA center in Saudi Arabia has introduced platforms with dashboards that monitor the supply of MERS-related materials on real-time basis and assist in tendering and customs processes. This system is bolstered by engaging private companies for transportation, ensuring this public-private partnership offers smoother flow of resources. Another innovative approach comes from the UAE. A joint effort between the Ministry of Climate Change and Environment, health authorities, and border control agencies has streamlined the import of animals. This joint effort has strictly regulated the supply chain of imported animals to be tested in the country of export before entering the country. This biosecurity-driven regulation has minimized the risk of transmission and ensured that only healthy livestock crosses borders.

To build long-term resilience in supply chains, several countries have focused on increasing local production capacities and reducing reliance on external suppliers. For example, In Kuwait, to ensure sustainability of supplies, the CPHL has an independent supply committee that is responsible for the continuous availability of diagnostic kits, reagents, accessories and instruments. This is funded from the MOH annual budget in collaboration with the central medical stores and engineering department. Saudi Arabia has invested in local production of critical supplies, such as PPE and sample collection materials, and has developed national stockpiles that is now being managed by NUPCO to ensure that these resources are readily available during emergencies. Locally manufactured supplies are prioritized in procurement processes, under the local content strategy. This strategy not only enhances the country's preparedness but also strengthens its ability to respond rapidly to future outbreaks without the delays associated with international supply chains. The GCC countries has an active joint procurement program in the GHC that supported GCC MS for emergency and business continuity.

Key Takeaway for Emergency Preparedness on Supply Chain Management

Real-Time Monitoring: Continuous inventory monitoring of essential resources like PPE, medications, diagnostic kits, and sample collection materials through electronic platforms and latest technology allows for swift responses and better resource allocation during outbreaks.

Supply Chain Flexibility: Flexibility in procurement and customs procedures for critical materials to respond quickly to emerging needs during health crises.

Public Private Partnerships: Engage or enable local manufacturers and transportation couriers to help in supplying and transporting materials that can be used in outbreak response.

Multisectoral Collaboration: Effective supply chain management requires multisectoral collaboration, including health, veterinary, agriculture, customs, finance and border control to ensure that all sectors are facilitating supply of materials that are critical for swift outbreak response.

Contingency Planning: Developing contingency plans for supply shortages and integrating emergency supply needs into high-level decision-making committees.

10. Risk Communication and Community Engagement

To effectively mitigate MERS-CoV transmission risks, GCC MS have employed dual communication strategies to reach different segments, the healthcare community as well as the general public. For instance, in Saudi Arabia, raising awareness was mainly focused on the medical community to minimize nosocomial infections by enhancing adherence to IPC measures. The public in Saudi Arabia was also educated on the importance of avoiding direct contact with camels and to promote the use of protective measures when handling camels. These messages were communicated through campaigns and educational materials that included billboards (Figures 15) television broadcasts and social media outreach. Public awareness has leveraged the critical mass in camel festivals, livestock markets and during Jumma Prayer speeches.

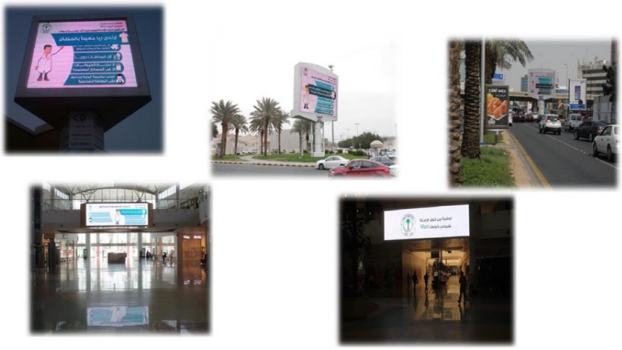


Figure 15: *Street billboards across Saudi Arabia were used in the campaign to raise public awareness about MERS*

Successful risk communication campaigns have been critical to target high-risk communities to prevent further MERS-CoV transmission. For example, since the emergence of MERS-CoV tailored health education activities are being delivered every year during the King Abdulaziz Camel Festival in Saudi Arabia, the largest camel festival in the world, to raise the awareness about MERS and other zoonotic diseases among camel handlers and owners. In Qatar, communication with camel owners, who initially resisted allowing access to their farms, was improved by involving community members and using local facilitators using local dialects. This participatory approach fostered trust and cooperation, demonstrating how direct community involvement can help to smoothen health communication (Figure 8).

Building trust and cooperation within communities during MERS outbreaks was crucial for the success of response efforts. Many countries prioritized transparency and clarity in their communications to ensure that the public felt informed and engaged. In Oman and Kuwait, ensuring that information was clear and easy to understand was key to gaining public trust. Data transparency was key, with public dashboards providing real-time information on case numbers and preventive measures. This transparency, seen across various countries, was vital in fostering public cooperation during the outbreak. As a result of effective communication efforts in Saudi Arabia, the community increasingly reported suspected animal to WEQAA, which further demonstrate the success of these campaigns in building trust. However, challenges in risk communication cannot be overlooked, particularly with cultural sensitivities and social barriers. For example, camel owners in Saudi Arabia initially resisted the idea of camels as a main animal host, especially that camels are mostly asymptomatic. Some owners were actively vocal in many social settings or platforms; for example, including real camel pictures in MERS awareness materials were resisted. This issue was considered, and a visual modification was applied by replacing images with infographics. This measure has reduced resistance and maintained message effectiveness. In Qatar, overcoming the reluctance of camel owners was resolved by involving trusted community figures to build trust and foster cooperation. Misinformation and language barriers, were noted in Oman, posed additional challenges, which were addressed through clear, multilingual messaging that provided simple and correct information to the high-risk communities.

Measuring the success of communication campaigns is essential to ensure their effectiveness. Short-term and long-term indicators were used in Saudi Arabia, which helped to measure the reach and impact of awareness activities, respectively. Short-term indicators included participation rates in awareness campaigns, immediate feedback mechanisms, and adherence to preventive measures among healthcare community. Long-term metrics included decrease in the incidence of cases compared with pre-campaign or reductions in healthcare-associated infections or the overall number of MERS cases. Qatar has also employed both immediate feedback mechanisms and long-term measures to gauge campaign impact, including reductions in case numbers and improved public cooperation during contact tracing activities. However, some GCC MS reported a lack of systematic feedback collection revealed gaps in the ability to fully assess the success of these campaigns, highlighting the need for more structured evaluation methods.

Following the One Health concept, multisectoral engagement was a key factor in the overall success of MERS communication. The involvement of a broad range of stakeholders including healthcare, animal and environmental agencies, community members, and media agencies was essential for ensuring a comprehensive communication strategy in addressing zoonotic diseases. Multisectoral collaboration in constructing communication strategy has ensured that the interconnected risks between humans and animals were communicated clearly to all stakeholders. Such approaches ensure that zoonotic diseases like MERS are managed in a holistic way, addressing the root causes of transmission at the human-animal-environment interface.

Key takeaway for emergency preparedness on risk communication and community engagement

Tailored Communication Strategies: Develop communication strategies that target high risk communities in the healthcare, animal sectors and the general public to address specific risks and preventive measures.

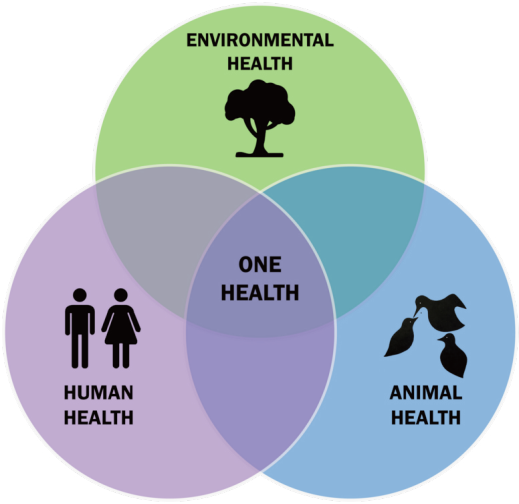
Community Involvement: Engage community leaders and local facilitators to enhance awareness communication and bridge cultural gaps.

Data Sharing: Maintaining transparency through open communication and real-time data sharing can foster public trust and increase public engagement.

Campaign Evaluation: Measure the impact of campaigns through both short-term and long-term metrics to assure the effectiveness of awareness campaigns.

Combating Misinformation: Address misinformation and rumors through clear, consistent, and fact-based communication strategy.

One Health Communication: Utilize the One Health framework to engage multiple sectors to the risk communication and response efforts, and highlight the interconnectedness of human, animal, and environmental health in risk communication.



11. One Health Activities

The implementation of the One Health concept across the GCC MS reflects a growing recognition of the interconnectedness of human, animal, and environmental health. The emergence of MERS-CoV has catalyzed this concept and put it into practice by exercising multisectoral integration to address zoonotic diseases challenges. The One Health approach has evolved across the region from previous high-level strategies to address zoonotic and vector-borne diseases. For example, the urgency of activating the One Health concept in Saudi Arabia has led to the reconstitution and reorganization of higher committees for zoonotic and vector-borne diseases.

A unified strategy was created, which resulted in nine strategic programs and thirty-six initiatives. The strategy also addressed the operational model to improve the multisectoral coordination and framework between human, animal, and environmental health sectors and establish the One Health system in the Kingdom. This integrated approach was timely and acted as the cornerstone in addressing MERS, particularly in managing the community-acquired cases. Qatar has practiced the One Health approach through Qatar National Outbreak Control Taskforce (OCT), which enabled timely surveillance, investigation, and enhanced diagnostic capacity. It also facilitated collaboration with international organizations (e.g., WHO, FAO, and CDC) to further strengthen the response. As a result, the One Health Roadmap was developed highlighting the value of multisectoral leadership and coordination. UAE has implemented one health approach by establishing Joint committee and integrated surveillance for information sharing and coordinated action between animal and human health sectors (Figure 16). In addition, joint research working groups were established to conduct surveys and serum sampling from workers at slaughterhouses and one animal market. Kuwait has a longstanding national-level Zoonotic Diseases Committee that expanded into a One Health Committee. This committee represents a multisectoral collaboration focused on surveillance, data sharing, regulating animal movements, and raising community awareness.

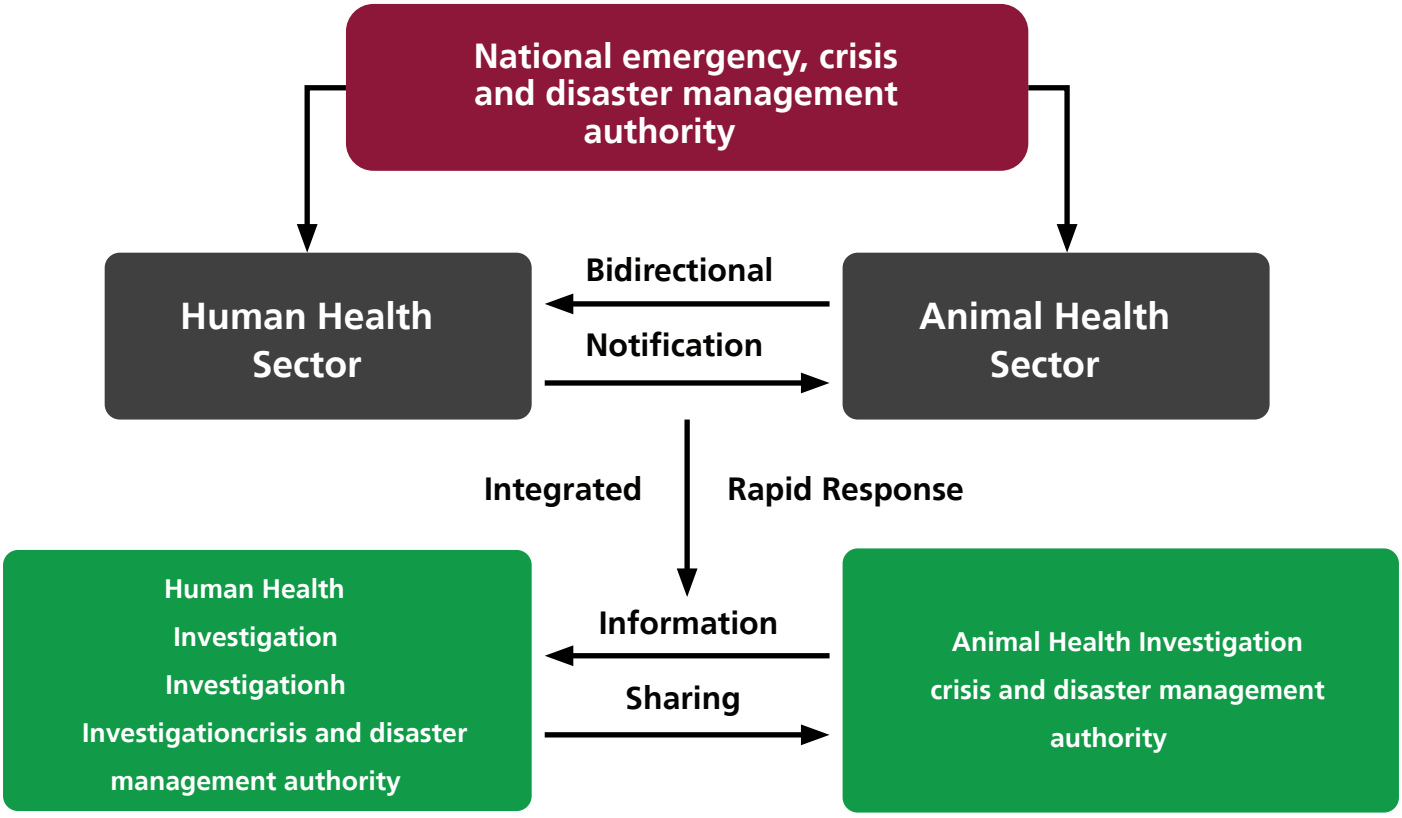


Figure 16: *Multisectoral collaboration in the UAE*

It is clear now that the success of an effective health program is directly dependent on clear governance and coordination mechanisms. Across the GCC MS the responsibilities and coordination among sectors have been managed through high-level committees that provide strategic oversight for the multisectoral operating teams on the ground. This approach facilitates active dialogue and holistic decision-

making, allowing coordinated implementation to respond to public health challenges. For example, the Joint Zoonotic Diseases Committee in Saudi Arabia has operationalized joint operations rooms across all regions to manage multisectoral response to MERS outbreak. In Oman, similar committees have long existed for communicable and vector-borne diseases, and they meet annually to discuss coordination for zoonotic outbreaks. This pre-existing structure made it easier to address MERS response and other zoonotic diseases such as Crimean–Congo hemorrhagic fever.

Throughout the GCC MS, multisector collaboration has been crucial to manage the spread of MERS, particularly at the human-animal interface. For example, in Saudi Arabia, the Ministry of Health has led the diagnosis and treatment of human cases, while Weqaa monitored and isolated camels, and the Ministry of Municipalities provided environmental support by monitoring animals markets and abattoir. This multisectoral and cross-sectional One Health collaboration was supervised and coordinated by the PHA and has been pivotal in controlling animal-human transmission of MERS-CoV, an approach that proven successful to address zoonotic diseases. Also, a joint response team that includes public health, environmental, and animal health sectors, has been instrumental in controlling outbreaks at the human-animal sectors. Another example comes from UAE where a one health integrated surveillance was applied after the occurrence of asymptomatic humans cases who had direct contact with infected camels imported from Oman in May 2015 (Table 2).

Table 2: A chronology of major events in a study of asymptomatic MERS-CoV infection in 2 humans after direct contact with infected dromedary camels imported from Oman to UAE, May 2015*

Date (May 2015)	Event
7	Contact 1 transported 8 dromedaries from Oman to the United Arab Emirates border. Contact 2 had direct contact with the dromedaries during sampling procedures at the camel screening center at the border. All 8 dromedaries were quarantined until test results were available on May 10.
10	All 8 dromedaries were found to be RT-PCR positive for MERS-CoV and were quarantined in a separate structure at the same border location. Active surveillance of persons with direct or indirect contact with the infected dromedaries was initiated. A sputum sample was obtained from contact 1; it tested positive for MER-CoV by RT-PCR on May 12, 2015.
12	A sample obtained from contact 1 on May 10 tested positive for MERS-CoV by RT-PCR; contact 1 was hospitalized in a negative-pressure room.
13	A follow-up sample was obtained from contact 1, and it tested positive for MERS by RT-PCR.†
14	A follow-up sample was obtained from contact 1, and it tested positive for MERS by RT-PCR. A nasal aspirate sample was obtained from contact 2; it tested positive for MERS by RT-PCR on May 17.† Samples were obtained from the infected dromedaries, and 5 were still MERS-CoV-positive by RT-PCR.
17	A sample obtained from contact 2 on May 14 tested positive for MERS-CoV by RT-PCR.
18	Contact 2 was admitted to a negative-pressure room in the same hospital as contact 1. Follow-up samples were obtained from contacts 1 and 2, and they tested negative for MERS-CoV by RT-PCR.
20	A follow-up sample was obtained from contact 2, and it tested negative for MERS-CoV by RT-PCR.
21	A follow-up sample was obtained from contact 2, and it tested negative for MERS-CoV by RT-PCR.
25	Follow-up samples from the 5 dromedaries tested negative for MERS-CoV by RT-PCR. All dromedaries were released from quarantine.
End of month	Contacts 1 and 2 were released uneventfully from the hospital.

*Contact 1 and 2, humans who had direct physical contact with infected dromedaries
†Samples subjected to sequencing analyses; ‡Exact date unknown

GCC MS have implemented various strategies on non-health sectors, including regulatory measures, multisectoral collaboration, and enhanced surveillance, to mitigate transmission risks. Efforts to address the animal and environmental aspects of MERS-CoV transmission have focused on limiting the virus's spread at the human-animal-environment interface, with a primary emphasis on camels as a known host. Regular screening and isolation of infected camels, enforcing regulations to restrict movement, and limiting human-animal exposures are critical to controlling MERS-CoV transmission. For example, Saudi Arabia enforces strict regulations on camel movement, and to eliminate risks throughout the year camel barns, farms, and slaughterhouses and markets were permanently relocated to city-sides outside residential areas to minimize exposures and mitigate transmission risks. The regulations also ensured the use of PPE by camel handlers and regular screening of camel herds, particularly those involved in festivals or in contact with confirmed human cases. Specific measures were also implemented during mass gathering events, such as relocating confirmed MERS-CoV camels outside the Hajj zone and declaring camel-free zones in both Hajj and Umrah areas. These measures aimed to emphasize the importance of biosecurity and IPC measures in reducing transmission risks.

The multisectoral collaborative efforts across sectors have significantly enhanced the understanding of MERS-CoV transmission dynamics. Genetic sequencing studies conducted on dromedary camels have provided critical insights into the virus's common clades in both humans and camels for better understanding of the transmission pathways, leading to targeted interventions. Through collaborations with the U.S. CDC, the ADAFSA in UAE has identified the genetic diversity of MERS-CoV strains, improving public health strategies for mitigating zoonotic transmission. Studies in Oman and Qatar have also contributed to a deeper understanding of transmission at the human-animal interface and genetic studies have highlighted the identification of a range of diverse viruses in upper respiratory animal samples. Continuous data sharing among sectors and across borders has also improved early detection and response strategies, helping to mitigate the spread of the virus at both the local and regional levels.

Managing MERS outbreaks was not done solely by specialized human, animal and environmental health personnel. Engaging communities and raising public awareness, particularly those involved in camel herding and farming has encouraged self-reporting of suspected symptoms. This engagement has enhanced public trust and increased compliance to stringent interventions, particularly among high-risk communities and professions. Public awareness campaigns targeting camel owners and animal workers (Figure 8) have also helped to reduce transmission risks by promoting the use of PPE and safe handling practices. Studies from Qatar highlighted the low perception of MERS risks among camel handlers and owners. Expanding public education campaigns and community engagement initiatives, especially in rural and high-risk communities was essential to encourage better compliance with IPC measures and improve early detection efforts. These efforts have demonstrated the importance of the One Health approach to manage the expertise and resources of multiple sectors to address the complex challenges that can occur with zoonotic disease outbreaks.

One of the main silver linings of MERS is that it put the One Health concept into practice in the GCC MS. This experience has advanced the strategic One Health approach to implemented practices with measurable outcomes across the region. These lessons have contributed to building more resilient and sustainable systems for more optimized response to current and future emerging and re-emerging zoonotic diseases. Figure 17 summarizes the One Health framework in Qatar to address MERS. Today, in Saudi Arabia for example, any human case involving zoonotic disease prompts an immediate response from the Weqaa, highlighting the optimized integration of human-animal health. Also, public health challenges occurred from vector-borne diseases are also being addressed following the One Health approach though multisectoral collaboration such as the national Dengue Committee and Rift Valley Fever Committees.

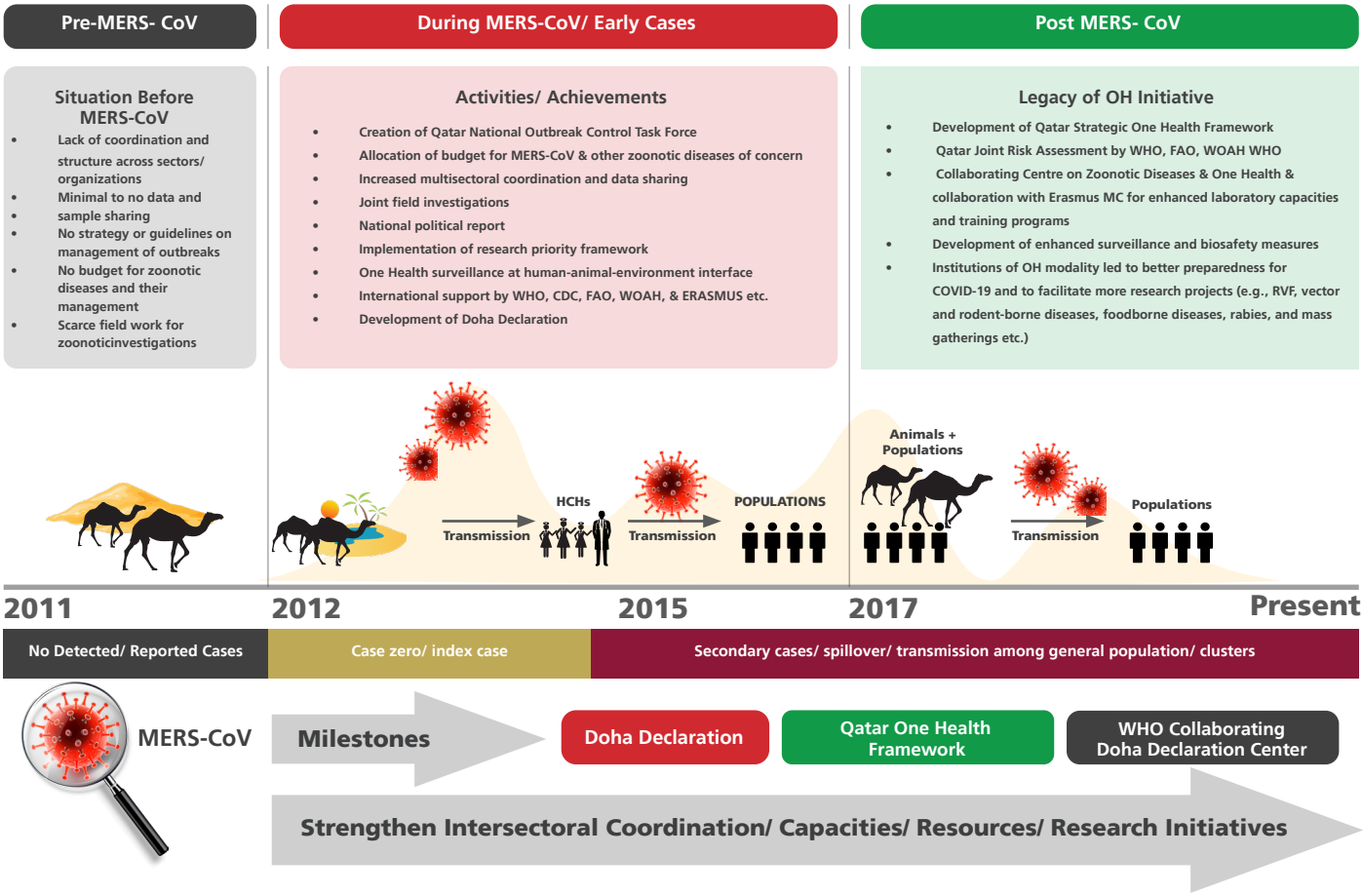


Figure 17: *Summary of the MERS One Health framework in Qatar.*

Key Takeaway for Emergency Preparedness on One Health Activities

Multisectoral Collaboration: The One Health approach requires collaboration among human health, animal health, and environmental sectors to effectively manage zoonotic diseases.

Governance: Establish high-level committees and enabling operational models, with defined roles and responsibilities for better coordination and decision-making process across the multiple sectors.

Learn from Challenges: MERS offered a great learning opportunity to strengthen the One Health approach. This highlights the importance of turning challenges into opportunities to optimize outbreak response systems.

Multisectoral Data Sharing: Data sharing and communication among the multiple sectors, stakeholders and high-risk communities is essential for the effective and timely management of zoonotic diseases, including genetic sequencing data of animal samples to understand transmission dynamics and molecular epidemiology of the zoonotic disease.

Sustainable One Health: Implementing sustainable One Health approach to address zoonotic diseases requires a permanent governance model that is regularly updated.

Routine Surveillance: Continuous and systematic surveillance of animals in high-risk areas is crucial. This includes the regular use of serological and molecular testing, particularly in high-risk regions with known animal-human transmissions.

Use of PPE in Animal and Environmental Sectors: Ensuring that personnel involved in animal handling and other individuals at risk use appropriate PPE.

- **Regulate Animal Movement:** Strict movement of identified animal host and the isolation of infected animals are essential to prevent disease transmission.

Community Awareness and Engagement: Enhance the awareness of animal owners, handlers, and the public regarding the associated risks of zoonotic diseases.

V. Regional and International Collaboration

The response to MERS across the GCC MS has benefited and strengthened through national, regional and international collaborations. These multisectoral collaborations are carried out among government agencies, academic institutions, international organizations, and other stakeholders, on surveillance, research, and response capabilities for MERS and other zoonotic diseases. Currently, the establishment of the Gulf CDC has created a more systematic and formal platform for regional and international collaborations and to coordinate response and other public health activities across all the GCC MS.

The WHO was very involved from a very early stage of the outbreak to support member states (Figure 18). Their involvement has improved surveillance in humans and animals and emphasized on the One Health approach through close collaboration and open communication with FAO and OIE and between sectors. Having a holistic global view, the WHO has helped to addressing public health and research questions and linking their results to action and included MERS in the WHO R&D Blueprint. Building capacity among the frontliners is a priority when responding to outbreaks. Thus, the WHO has collaboratively carried out technical trainings in many areas including in laboratory testing, sampling, triage, risk communication and IPC with special focus on National Rapid Response Team Training. To maximize the learning and training opportunities OpenWHO has published Massive Open Online Courses about MERS in several languages. To assure standardization and unification in outbreak response and preparedness the WHO has published several guidelines about MERS specific outbreak investigation protocols, clinical characterization Protocol for SARI, clinical studies including clinical trial standardized protocols, investigation guidance and material transfer agreement tool.

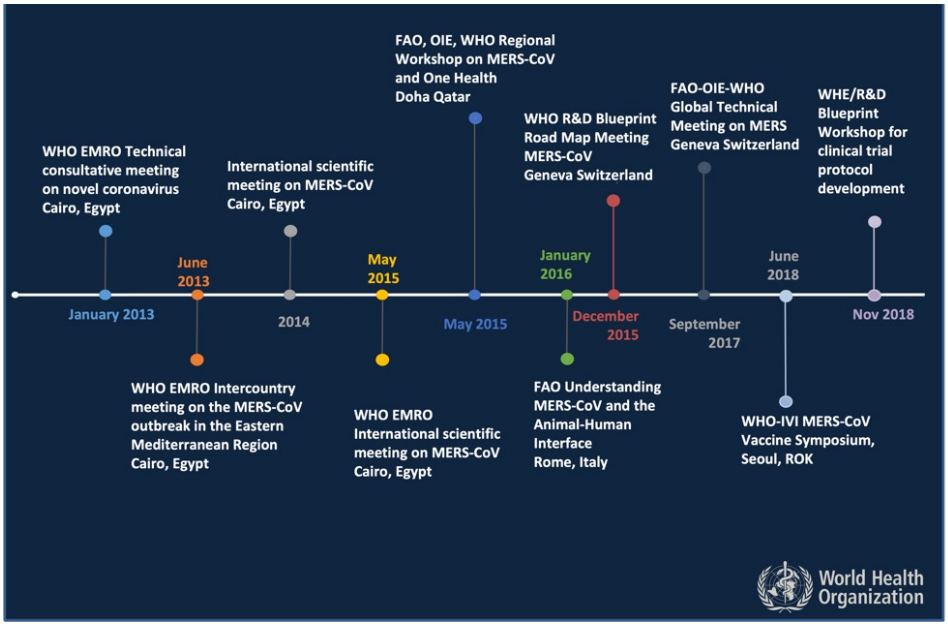


Figure 18: *Timeline summarizing WHO involvement and support in addressing MERS outbreak*

Some GCC MS have utilized the lesson learned from MERS and established structured collaborating centers with international agencies to maintain collaboration on a global level. For example, in 2021 Saudi Arabia has established a WHO-MERS Collaboration Centre at PHA, which focuses on the development of evidence-based guidelines, support the WHO in developing and strengthening the surveillance and preparedness systems and to act as a reference center to build the capabilities to respond and control MERS outbreaks. In 2021, the center actively participated in Global Technical Meeting on MERS-CoV and Other Emerging Zoonotic Coronaviruses. In 2023, in collaboration with the WHO, WOAH, FAO and UNEP the WHO-MERS-CoV Collaboration Centre in PHA convened the MERS-GLOBAL meeting a biennial Quadripartite Global Technical Meeting that was held in Riyadh, to address MERS response and Other Emerging Zoonotic Coronaviruses.

WHO-MERS Collaboration Centre supported WHO in generating and disseminating evidence-based MERS-COV clinical and epidemiological information and supported the engagements of health experts from Saudi Arabia to participate on WHO Technical Advisory Groups meetings. The WHO-MERS Collaboration Centre is planning to provide technical assistance and laboratory capacity building to strengthen and expand the WHO EMR respiratory laboratory network. In the UAE, ADAFSA has established a WOAH Collaborating Centre in Quality Management System, and in Camel Diseases in the Middle East in recognition of its scientific and technical efforts at the national and international levels. As a result, the ADAFSA in the UAE has established the CAMENET Initiative, which involves 9 countries in the region, namely GCC MS, Yemen, Iraq, and Jordan. This initiative focuses on zoonotic disease management, specifically MERS, by promoting regional information exchange and capacity-building in animal health surveillance and control measures. In addition, in UAE Abdu Dhabi Public Health Center established collaboration with WHO to be recognized as WHO Collaborating Center for Emerging Respiratory Infections with strong focus on strengthening surveillance and research for unknown or emerging infections.

Other collaborative efforts by GCC MS have also demonstrated success in controlling MERS outbreaks, improving surveillance, and facilitating capacity building. For example, In Qatar, MERS joint outbreak investigation teams included national health organizations, academic institutes, and international partners, such as WHO, FAO, WOAH, and the Netherlands-based EMC. This ongoing collaboration was leveraged when convening the Joint Risk Assessment workshop in 2022, in collaboration with 11 local institutes in Qatar, EMRO-WHO, FAO, and WOAH (Figure 19). The purpose of this workshop was to kick-start One Health activities and facilitate the implementation of the One Health Framework, with the aim of strengthening the healthcare infrastructure to combat the current and future impact of zoonotic diseases. Kuwait's IHR Section at the Kuwaiti CDC maintains a robust network for data sharing and information verification with the GCC MS and WHO's EMRO office.

Figure 19: *Examples of workshops and educational events addressing MERS response in Qatar.*

ocal and international collaboration with academic institutes on research endeavors have been the backbone to complement knowledge gaps in MERS response. For example, the ChAdOx1 MERS camel vaccine was a result of a collaborative project between University of Oxford and KAIMRC in Saudi Arabia (Figure 20). The WGS of selected MERS-CoV samples isolated from camels in Saudi Arabia were carried out at Hong Kong University. Qatar University also offered the needed support to WGS and bioinformatic analyses of MERS-CoV isolates. Many other universities across the GCC MS have embarked on important scientific research studies in collaboration with international institutes.

Figure 20: Collaborative evaluation of a MERS vaccine candidate in dromedaries using a challenge model based on natural transmission in camels [56].

Key takeaway for Emergency Preparedness on Regional Collaboration

Establish Sustainable Collaboration: Initiate formal structures such as WHO or/and WOAH collaborating to facilitate rapid and effective coordination among international agencies during outbreaks.

Leverage Local Multisectoral Collaboration: Rely on the One Health frameworks to collaborate with human, animal, and environmental health sectors for controlling zoonotic diseases.

Training Programs: Organize capacity-building workshops involving national and international stakeholders to improve preparedness for zoonotic diseases.

Strengthen Regional Collaboration: Strengthen regional networks through GCC-CDC to harmonize zoonotic disease control measures, enhance cross-border dialogue, develop standardized protocols and guidelines and manage regional outbreaks effectively.

Facilitate Academic Collaborations: Support, facilitate and fund joint research projects that focus on vaccine development, genetic sequencing, and innovative diagnostic tools to accelerate the development of critical interventions during outbreaks and build local capacities.

VI. Gaps and Challenges on MERS Prevention and Control

MERS response efforts across the GCC MS have highlighted several challenges and gaps that have impacted the effectiveness of outbreak management. Effective governance is crucial in efficient outbreak response; however, the fragmentation of governance structures was noted as a challenge in MERS management in a few countries in the region. For example, some centers in the GCC MS are focused on animal health, human health, or environmental health, which can lead to segmentation and coordination challenges, particularly in health-based joint decision-making and operational integration. In some GCC MS, there have been unclarity among some stakeholders, as well as inadequate integration between human and animal surveillance systems. This, coupled with, limited communication, collaboration, and trust across sectors, has led to inefficient responses. Additionally, the absence of a unified electronic epidemiological information system with real-time data sharing has hindered synchronized decision-making. One Health committees can serve as a platform to address these challenges

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Resource allocation for MERS remains a significant challenge, particularly in supply chain management. In some countries, the specific needs in of multiple sectors places a strain on the budgets, making it difficult to prioritize essential supplies. The lack of reliable predictive models for estimating resource requirements further complicates the situation, resulting in inconsistent resource distribution during MERS outbreaks. Several GCC MS reported funding limitations, particularly for continuous animal health surveillance, laboratory testing, and equipment procurement, which hinder sustainable preparedness.

Preventing the transmission of MERS-CoV presents unique challenges. The diverse cultural background of the populations in the GCC MS, along with language barriers, makes it difficult to effectively communicate risk information, necessitating additional resources to ensure widespread delivery of risk communication messages. Monitoring the disease transmission among illegal immigrants is another unique local challenge, though these individuals they still receive treatment. Furthermore, risk communication of MERS in general, and particularly in convincing high-value camel owners to adopt preventive measures is challenging, given the cultural, emotional, and economic importance of their camels. Lack of understanding of zoonotic diseases in general among some populations emphasizes the need for more targeted awareness campaigns. Enforcement of IPC measures are vital for outbreak control and response, but effective community engagement remains the cornerstone for sustainable prevention of zoonotic emerging and re-emerging diseases.

Implementing and practicing the One Health approach in the prevention and control of MERS across the GCC MS can be further improved and optimized. Some GCC MS have identified the need to establish One Health committees or task forces at national and governorate levels. This will improve collaboration, communication, and

coordination between human health, animal health, and environmental sectors as well as upscaling the local legislations concerning prevention and controlling of MERS and other zoonotic diseases outbreak. Although the theme of the One Health approach is to work together, joint investigation teams are not consistently formed, with human and animal health sectors often working independently in some countries. This limits the potential for a comprehensive response that integrates surveillance and control efforts. Similarly, in some GCC MS, investigation teams are primarily sector-specific, indicating a need for more coordinated multisectoral efforts. Barriers to cross-sector communication are also identified as a challenge in other GCC MS. Elevating trust to effectively communicate among multisectoral stakeholders would infuse the practice of One Health collaboration. Additionally, there is limited emphasis on the One Health concept at academic and early career training levels where they need to be introduced to new medical, veterinary and medical sciences students. Addressing these challenges will require the establishment of integrated One Health committees and task forces at national and sub-national levels. These committees will advocate for designing academic and training programs among different specialties across the human, animal, and environmental health sectors.

Research and development (R&D) efforts across the region have faced limitations in translating MERS findings into policy and practice. In GCC MS, a lack of large-scale applied research projects that can inform policy decisions, was recognized as a challenge, referring mostly to the scattered efforts in MERS R&D. Harmonizing research agendas across universities, research centers, and sectors is crucial to ensure a cohesive approach to MERS response and prevention. This role can be unified by a centralized entity that can create a unified priority mission and collaborative funding. Another common challenge identified in most of the GCC MS is the regulatory challenges in accessing and utilizing clinical samples in R&D, which delays research progress and impacts timely response efforts. Applying restrictions on data sharing can limit collaborative research potential and delay evidence-based decision-making. On the contrary, establishing open data platforms that enable transparent research can help in developing tailored policy development to address more effective response strategies.

Key Takeaway for Emergency Preparedness

Establish One Health Governance Structures to ensure coordination among human, animal, and environmental health sectors, supported with electronic information system for real-time data sharing across sectors to enhance instant response.

Tailored Communication Strategies that are culturally sensitive and target the majority of subpopulations and engage community leaders to effectively enhance public understanding and response to misconceptions of zoonotic risks among all community segments.

Integrated Supply Chain systems are designed to respond to the demands of human, animal, and environmental health sectors, establishing rapid distribution channels for critical resources.

Focused research Missions to ensure R&D are relevant and can be translated into practical interventions. This can be supported with open data platforms and dedicated funding schemes to enable transparent research and facilitate evidence-based policymaking.

Training and Education about One Health approach for health workers, veterinarians, and environmental specialists, emphasizing One Health principles. accelerate the development of critical interventions during outbreaks and build local capacities.

VII. Ways Forward

GCC MS have plans and strategies to further improve prevention and control of MERS, emphasizing multisectoral collaboration through One Health committees, and capacity building across human, animal, and environmental health sectors. All GCC countries are building on the accumulated experience to further sustain the best practices and gains as well as to overcome any challenges or gaps. Table 3 presents a few non-inclusive examples of some planned efforts and activities that the GCC MS are moving towards, captured in this report.

Country	Way Forward
UAE	• Advance MERS response through enhanced diagnostics, surveillance, and One Health integration. • Strengthen disease detection, risk management, and cross-border controls on a multisectoral levels. • Train personnel, improve diagnostics, expand biosecurity measures, and foster collaboration with global partners like WHO and the U.S. CDC.
Bahrain	• Enhance MERS-CoV surveillance, laboratory capacity, and multisectoral coordination. • Build laboratory capacities through continuous training programs. • Apply genome sequencing and instant data sharing. • Leverage regional data-sharing mechanisms to maintain preparedness.
Saudi Arabia	• Conduct simulation workshops with the WHO to update MERS guidelines. • The WHO-MERS collaboration center will coordinate technical collaboration with the CDC, WHO, FAO, and other GCC countries via Gulf CDC. • Weqaa improves reporting and regulating IPC and surveillance practices of MERS-CoV in camel-related activities. • Launch a One Health dashboard by 2026, along with national One Health operation rooms to integrate surveillance and response efforts.
Oman	• Advance multisectoral engagement, training, and improve surveillance, particularly within the animal sector. • Establish a multisectoral task force and committees for a One Health at national and governorate levels. • Emphasize training, laboratories enhancement, and the activation of event-based surveillance systems with a strong focus on involving the private sector in supporting One Health initiatives. • Integrate the One Health concept into medical education. • Strengthen joint surveillance, capacity building, and data exchange through partnerships with regional and international organizations.
Qatar	• Advance research endeavors and strengthening One Health capacities. • Activate the One Health framework to improve public health responses to better address current and future threats imposed by zoonotic diseases. Strengthen the existing partnerships with international organizations such as the WHO, FAO, and WOAH to carry out joint workshops and capacity-building.
Kuwait	• Prioritize surveillance, One Health multisectoral integrations, and capacity building. • Prevent MERS-CoV transmission and strengthen animal health surveillance. • Conduct Animal surveillance through random sampling of animals every six months, along regular inspections of animal facilities, and improved isolation protocols for infected livestock. • Adaptable protocols to enable the monitoring of other zoonotic diseases.

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