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Global technical meeting on MERS-CoV and other emerging zoonotic coronaviruses

Virtual meeting

15–16 November 2021

FAO ANIMAL PRODUCTION AND HEALTH / **REPORT 16**

Global technical meeting on MERS-CoV and other emerging zoonotic coronaviruses

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Authors

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Contents

Abbreviations and acronyms

EMFLU	Eastern Mediterranean Flu network
EMRO	Eastern Mediterranean Regional Office (WHO)
FAO	Food and Agriculture Organization of the United Nations
GISRS	Global Influenza Surveillance and Response System
IPC	Infection prevention and control
IZSAM	Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise "Giuseppe Caporale"
KAIMRC	King Abdullah International Medical Research Center
KDCA	Korea Disease Control and Prevention Agency
MERS-CoV	Middle East respiratory syndrome coronavirus
PPE	Personal protective equipment
RCCE	Risk Communication and Community Engagement
R&D	Research and development
SARS-CoV	Severe acute respiratory syndrome coronavirus
STAR-IDAZ	Global Strategic Alliances for the Coordination of Research on the Major Infectious Diseases of Animals and Zoonoses
WHO	World Health Organization
WOAH	World Organisation for Animal Health (formerly OIE)

Background

Since its identification in Saudi Arabia in 2012, Middle East respiratory syndrome coronavirus (MERS-CoV) has continued to pose significant public health, health security and economic threats to the global community. To date, more than 2 500 cases of human infection have been reported to the World Health Organization (WHO), with cases exported to all regions of the globe (WHO, 2022).

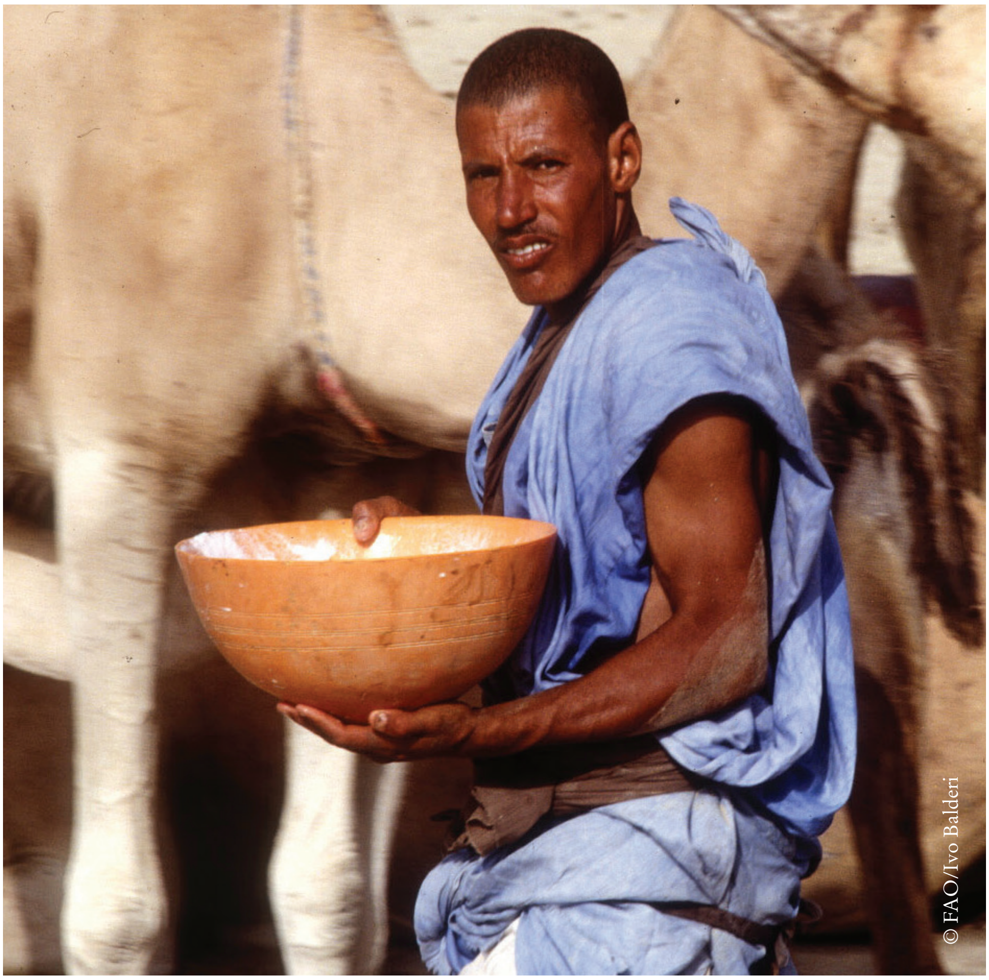
Over the last nine years, the Food and Agriculture Organization of the United Nations (FAO), WHO and the World Organisation for Animal Health (WOAH) have worked with Member States, public health professionals and experts across multiple sectors and technical disciplines to improve preparedness and response capacities for MERS-CoV and other high-threat zoonotic pathogens around the world. This work continues to bring together human and animal health experts from affected and at-risk countries, scientists and subject matter experts of high-threat respiratory pathogens to review the latest scientific evidence on MERS-CoV and improve multisectoral collaboration. As a follow-up to previous technical meetings on MERS-CoV hosted by FAO, WHO and WOAH (FAO, 2014, 2015, 2016; FAO-OIE-WHO MERS Technical Working Group, 2018), a global technical meeting was convened virtually on 15–16 November 2021 to share the latest findings from accelerated efforts to implement the MERS-CoV public health research agenda and research and development (R&D) road map, in the context of the ongoing COVID-19 pandemic.

Objectives

The specific objectives of the meeting were to:

1) summarize the latest scientific findings and country experiences of MERS-CoV;
2) facilitate coordination and communication between animal, human and environmental health sectors in MERS-CoV-specific and general outbreak preparedness and response;
3) highlight how MERS-CoV work has contributed to the global effort against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2);
4) apply lessons learned from COVID-19 to the control and prevention of MERS-CoV and other emerging zoonotic coronaviruses; and
5) summarize priority actions and research for the continued advancement in the control and prevention of MERS-CoV.

The meeting, held over two half days in English, with simultaneous translation in Arabic and French, was attended by almost 200 participants from 36 countries. The following sections represent the information presented.



Welcome and opening remarks

Haleema Al Serehi, Ministry of Health, Saudi Arabia; Montserrat Arroyo, WOAH; Michael Ryan and Maria Van Kerkhove, WHO; Keith Sumption, FAO

The ongoing COVID-19 pandemic has highlighted the significant public health and economic threats that coronaviruses pose, as well as the critical importance of preparedness, readiness and rapid responses for high-threat respiratory pathogens.

MERS-CoV research, prevention and preparedness efforts helped accelerate the ongoing global response to COVID-19, with early guidance and response actions for COVID-19 having drawn significantly from existing technical guidance and networks previously established for MERS-CoV. COVID-19 is now having a substantial impact on MERS-CoV surveillance and research activities, underlining the importance of global collaboration and integrated efforts across diseases.

MERS-CoV is still a public health threat, with gaps in knowledge and countermeasures remaining, including the availability of safe and effective therapeutics and vaccines. A comprehensive One Health approach[1] and better collaboration between animal and human health sectors is crucial to progress MERS-CoV work, which includes the setting of international standards for reporting, strong governance in both sectors, political and financial commitments, and leadership. To ensure that MERS-CoV, and more broadly, high-threat respiratory pathogen preparedness, remains a high priority, global commitments must be made.

[1] One Health is an integrated, unifying approach that aims to sustainably balance and optimize the health of people, animals and ecosystems (FAO, OIE, WHO and UNEP, 2021).

PLENARY SESSION 1

How MERS-CoV supported the COVID-19 response

Chair: Maria Van Kerkhove, WHO

GLOBAL PREPAREDNESS FOR MERS-COV AND THE COVID-19 RESPONSE

Maria Van Kerkhove, WHO

Since MERS-CoV was first identified in 2012, its global epidemiology has been characterized by the sporadic introduction of the virus from dromedary camels into the human population, and the amplification of human-to-human transmission in health-care settings, some of which have resulted in substantial outbreaks. To date, there have been more than 2 500 laboratory-confirmed cases of MERS-CoV and 888 related deaths reported in 27 countries. National responses to MERS-CoV across WHO regions have led to improved surveillance and prevention, particularly in hospital settings, and more collaboration between animal, human and environmental health sectors. The systems and guidance that have been built and developed for MERS-CoV set a strong foundation to respond rapidly to COVID-19 in January 2020 and enabled early technical guidance and WHO's COVID-19 Strategic Preparedness and Response Plan to be issued in a timely manner.

Since early 2020, identified cases of MERS-CoV reported globally have declined, but this is likely due to redirected surveillance activities and the impact of public health and social measures for COVID-19. Moving forwards, MERS-CoV preparedness and response must build on lessons and knowledge learned from COVID-19, with actions adopted that are appropriate for managing multiple respiratory disease threats in a more comprehensive and integrated manner. Strengthening integrated respiratory pathogen surveillance, sequencing and bioinformatics capacity will be crucial, as will partnerships that enable a One Health approach to preventing zoonotic pathogen spillover. Pandemic preparedness must be constant – there is no "peacetime". Governments, health officials and international agencies must therefore remain vigilant to detect and respond to cases of MERS-CoV.

MERS-COV AND COVID-19 VACCINE DEVELOPMENT

Sarah Gilbert, University of Oxford, United Kingdom

ChAdOx1, a chimpanzee adenovirus vaccine vector, has been developed and used for vaccine candidates against several infections, including SARS-CoV-2 and MERS-CoV. The ChAdOx1 MERS vaccine was developed by the University of Oxford's MERS-CoV vaccine development programme using the MERS-CoV spike protein.

Preclinical studies show efficacy in mice and monkeys (Alharbi *et al.*, 2017, 2019; Munster *et al.*, 2017; van Doremalen *et al.*, 2020b), with one dose generating a well-maintained antibody response in human volunteers from Oxford (United Kingdom) and Riyadh (Saudi Arabia) (Bosaeed *et al.*, 2022; Folegatti *et al.*, 2020).

Work to develop the ChAdOx1 MERS vaccine enabled quick and expanded development for a similar SARS-CoV-2 vaccine, which showed that homologous boosting and longer intervals between a first and second dose increases the antibody response. The technology transfer work and partnership with AstraZeneca also allowed for the large-scale development of the vaccine, leading to the distribution of 1.9 billion doses globally at no profit to more than 170 countries.

MERS-CoV vaccine trials have been largely halted by COVID-19. Moving forwards, two-dose and phase 2 trials with the ChAdOx1 MERS vaccine are planned to take place in Saudi Arabia and the United Kingdom, with a focus on older age groups and individuals with comorbidities. Since large phase 3 trials will be difficult due to the small number of infections at any one time, vaccine licensure plans could consider using immunobridging from SARS-CoV-2 vaccine data and non-human primate studies to determine MERS-CoV vaccine effectiveness. Parallel vaccine development and efficacy studies in camels are also important, as they aim to reduce zoonotic transmission.

PANEL DISCUSSION: HOW THE PANDEMIC HAS AFFECTED WORK ON MERS-COV

Facilitator: Shagun Khare, WHO
Haleema Al Serehi, Ministry of Health, Saudi Arabia; Sarah Gilbert, University of Oxford, United Kingdom; Gounalan Pavade, WOAH; Maria Van Kerkhove, WHO; Sophie von Dobschuetz, FAO

The COVID-19 pandemic disrupted the MERS-CoV work of organizations and institutions worldwide, impacting both human and animal health-related MERS-CoV resources, capacity building and surveillance. This disruption may have influenced the lower number of cases reported in 2020 and 2021.

Despite this impact, the pandemic has expanded the structures and networks developed for MERS-CoV, helping to strengthen overall preparedness and response for MERS-CoV and other emerging infectious diseases. The pandemic has also enhanced collaboration between human and animal health sectors and has led to a wider acceptance of the One Health approach to pandemic prevention. Although COVID-19 has increased awareness of the threat of emerging coronaviruses, work is still needed to engage the global community around the risk of MERS-CoV. COVID-19 research, including on countermeasures, therapeutics and vaccines, has advanced significantly, much of which can be used to progress MERS-CoV work.

EASTERN MEDITERRANEAN REGIONAL MERS-COV MEETING SUMMARY

Abdinasir Abubakar, WHO Eastern Mediterranean Regional Office (EMRO)

In August 2021, WHO EMRO convened a technical MERS-COV meeting, which focused on the impact of COVID-19 in the EMRO region and how to progress MERS-CoV public health activities. During the meeting it was highlighted that MERS-CoV surveillance and research efforts had been redirected towards COVID-19, supported by systems, investigation tools and capacities previously put in place by MERS-CoV work. MERS-CoV preparedness and response tools had also been adapted for COVID-19, as had testing strategies. It was also highlighted that COVID-19 had expanded laboratory and epidemiological capacities, which could now be leveraged for MERS-CoV, including risk communication. Countries were also reported to have used a One Health approach for MERS-CoV in relation to expanded camel surveillance.

Recommendations from the meeting included reviving the attention given to MERS-CoV as a global health threat, reactivating MERS-CoV surveillance in high-risk countries and integrating surveillance with that of other respiratory diseases, updating technical guidance and tools using knowledge gained from COVID-19, increasing investment in MERS-CoV research and the development of vaccines and multiplex diagnostics, and enhancing partnerships to implement a One Health approach.

PLENARY SESSION 2
Assessing the risks of MERS-CoV and other coronaviruses

Chair: Maria Van Kerkhove, WHO

UPDATE ON MERS-COV IN ANIMALS

Emma Gardner, FAO; Gounalan Pavade, WOAH

Dromedary camels are the reservoir species for MERS-CoV and the main source of transmission to humans. Age and sex are individual risk factors for MERS-CoV infection in camels, as are herd-related factors such as herd size, management practices and connectivity (Dighe *et al*., 2019; Holloway *et al*., 2021; Sitawa *et al*., 2020). Understanding the natural history of MERS-CoV and immunity in camels is a research priority, with preliminary unpublished findings from longitudinal studies suggesting that MERS-CoV antibodies in dromedary camels are generally stable and long lasting. However, their role in immunity is unclear given that there is evidence of MERS-CoV reinfection (Alharbi, Kulkarni and Falzarano, 2021).

Modes of MERS-CoV transmission in camels is another research priority. MERS-CoV has been detected in milk and seminal fluid, and may also be present in camel breath (Hemida *et al*., 2020a, 2020c; Reusken *et al*., 2014). Continual surveillance is needed to determine MERS-CoV seasonality, as variable climatic conditions and husbandry practices across regions may influence viral circulation patterns.

Outside the Arabian Peninsula, MERS-CoV appears to be endemic in dromedary camels across Africa, with evidence of zoonotic transmission despite an absence of reported human cases. Genomic surveillance, the engagement of camel stakeholders and the development of feasible One Health interventions in MERS-CoV circulation areas outside the Arabian Peninsula are therefore needed for the early detection of genetic changes and the establishment of sustainable interventions to prevent zoonotic transmission.

MERS-CoV infection in dromedary camels is listed as a disease in chapter 1.3 of the WOAH Terrestrial Animal Health Code (WOAH, 2021a) as it presents a significant public health threat, especially for people in close direct and indirect contact with dromedary camels. The WOAH Manual of Diagnostic Tests and Vaccines for Terrestrial Animals 2022 contains a dedicated chapter on MERS-CoV, which references laboratory standards and provides validated, internationally-agreed procedures for confirming MERS-CoV in animals (WOAH, 2021b). The case definition for reporting confirmed cases of MERS-CoV in dromedary camels has been updated (WOAH, 2019) and a new chapter on MERS-CoV is planned for the WOAH Terrestrial Animal Health Code. This new chapter will provide recommendations on surveillance and guidance for facilitating the safe trade of dromedary camels and their products and will also highlight the importance of surveillance among dromedary camels to prevent and control the disease in humans.

MERS-COV RISK AT THE ANIMAL-HUMAN INTERFACE

Malik Peiris, University of Hong Kong, Hong Kong Special Administrative Region

Dromedary camel trade routes and practices are common in parts of Africa and the Arabian Peninsula, but put humans in direct contact with camels or their products, which are potential sources of MERS-CoV transmission. Recent evidence based on biologically confirmed cases reported to WHO found that direct exposure to dromedary camels and the consumption of unpasteurized camel milk are risk factors for primary MERS-CoV infection (Conzade *et al*., 2018).

Despite a limited number of human infections reported outside the Arabian Peninsula, recent seroprevalence studies in occupationally exposed populations, MERS-CoV-specific T-cell responses and asymptomatic infections in camel-exposed African populations indicate that there is zoonotic transmission in Africa (Abbad *et al*., 2019; Mok *et al*., 2021; Munyua *et al*., 2021). MERS-CoV appears to have three distinct clades: clade A, clade B and clade C. Compared with clade A and B viruses found in Saudi Arabia, clade C viruses circulating in Africa have lower replication competence and less efficient viral entry, suggesting that MERS-CoV infection in Africa may be less transmissible and virulent (Zhou *et al*., 2021). As clade B viruses appear to outcompete clade C viruses in camels (El-Kafrawy *et al*., 2019; Hemida *et al*., 2020b), the importation of MERS-CoV from the Arabian Peninsula into Africa could have serious public health consequences.

OVERVIEW OF CORONAVIRUSES IN ANIMALS

Alessio Lorusso, Istituto Zooprofilattico Sperimentale dell'Abruzzo e del Molise "Giuseppe Caporale" (IZSAM), Italy

Coronaviruses constitute a broad group of viruses, some of which are zoonotic. They can cause a range of diseases from mild to severe respiratory, enteric and systemic infections. Coronaviruses are widely prevalent and genetically diverse, have high mutation frequency and significant recombination events and can jump across species. These events can affect tissue and host tropism and virulence, resulting in significant human and animal health consequences. Some low-pathogenic human coronaviruses have originated from bats and rodents via intermediate animal hosts, with amino acid changes responsible for enabling animal-to-human transmission. Importantly, adaptation to humans is not necessary for human infection, emphasizing the continual threat that coronaviruses pose. There is also a remote possibility of MERS-CoV recombination with SARS-CoV-2.

ASSESSING THE RISK OF NOSOCOMIAL OUTBREAKS

Muhammad A. Halwani, Al-Baha University, Saudi Arabia

MERS-CoV outbreaks have often resulted from nosocomial transmission, particularly in 2014 and 2015. An assessment of one of the 2015 MERS-CoV outbreaks in a Riyadh hospital found that the index case was the source of transmission to other nearby patients, and that health workers who had cared for the index case had spread the infection further due to poor knowledge and use of infection prevention and control (IPC) practices. Some health workers were mildly affected or asymptomatic, so the risk of spread from these individuals is unclear.

Substantial progress in reducing nosocomial outbreaks has been made since then. This has been achieved through the wearing and replacement of appropriate personal protective equipment (PPE), including N95 masks during aerosol-generating procedures with suspected or known positive patients, increased bed space for patients in emergency rooms, the use of physical barriers between MERS-CoV patient beds and the strengthening of hospital IPC policy and practices.

PARALLEL SESSION 1
Surveillance challenges

Chair: Ryan Aguanno, FAO

INTEGRATING MERS-COV, SARS-COV AND NCOV INTO RESPIRATORY DISEASE SURVEILLANCE: GISRS+

Stefano Tempia, WHO EMRO

The Global Influenza Surveillance and Response System (GISRS) is a mechanism for the surveillance, characterization and reporting of influenza viruses. GISRS+ extends surveillance beyond influenza viruses to include SARS-CoV-2 and other respiratory viruses with epidemic and pandemic potential. Interim guidelines on the integration of SARS-CoV-2 into influenza sentinel surveillance (GISRS+) were issued in October 2021. These integrated sentinel surveillance systems will be complementary to other forms of surveillance and will use the same principles that have guided seasonal influenza surveillance. The EMRO region has significant laboratory capacity for influenza, including molecular detection, which can be used for MERS-CoV. The Eastern Mediterranean Flu (EMFLU) network's online platform has been adapted to include COVID-19 epidemiological data and laboratory results.

Integrating MERS-CoV into GISRS+ requires further conceptualization, taking into account variable risks across regions and countries and the lack of multiplex diagnostics for MERS-CoV, SARS-CoV-2 and influenza. Appropriate testing strategies for global and national-level surveillance will also need to be determined.

A DECADE OF MERS-COV IN SAUDI ARABIA: SURVEILLANCE, THE CURRENT SITUATION AND LESSONS LEARNED

Ibrahim Ahmad Qasim, Ministry of Environment, Water and Agriculture, Saudi Arabia

Saudi Arabia has built significant capacity in MERS-CoV preparedness and response. Risk assessments based on human case data and seroprevalence in camel populations have enabled the development of risk mapping for MERS-CoV at a regional level with appropriate standard operating procedures based on risk categories. Animal health surveillance has been strengthened and continuous professional development for animal health workers should be implemented to maintain this capacity and level of preparedness. Methodologies used for assessing MERS-CoV risk factors among camels can be adopted for any emerging and/or re-emerging zoonotic disease, including appropriate mitigation protocols. The One Health approach has been incorporated into preparedness and decision-making in Saudi Arabia. More joint international projects could facilitate further product development, as in the case of the collaboration that resulted in the evaluation of the ChAdOx1 MERS vaccine.

HUMAN SURVEILLANCE AT MASS GATHERINGS

Anas Abdulhafeez Khan, Ministry of Health, Saudi Arabia

Saudi Arabia hosts 2–3 million pilgrims annually for hajj, which creates many public health operational challenges, especially for infectious disease surveillance and control. Saudi Arabia deploys enhanced infectious disease surveillance for the two months around hajj and builds on the existing national notifiable disease surveillance system. Active case-finding and real-time updates of suspected and confirmed cases at key points of entry, health-care facilities and medical missions are part of the hajj surveillance system. Fixed and mobile teams report to hajj coordination and executive committees and WHO for response actions and feedback, which is also supported by the web-based Saudi Health Electronic Surveillance Network and outbreak management system. Medical hajj offices from countries that send pilgrims are also included within the system and must comply with standard processes for waste disposal and the reporting of notifiable diseases, though under-reporting is a current challenge. This approach has been used for both MERS-CoV and, more recently, COVID-19. Moving forwards, Saudi Arabia is planning to implement a hajj health early warning system as one of its Vision 2030 initiatives, which will strengthen risk communication, use formal and informal (social media and news feeds) data for intelligence and require global collaboration.

ONE HEALTH OUTBREAK INVESTIGATION MILESTONES AND METRICS

Mark Smolinski, Ending Pandemics

Ending Pandemics is an initiative to expand epidemic intelligence to predict, prevent and detect outbreaks faster. Key parts of its approach include working with the public for participatory surveillance, using One Health principles, expanding epidemic intelligence through communities and One Health dashboards, collaborating with neighbouring countries to strengthen regional networks and measuring progress. To measure progress, the initiative has developed outbreak milestone definitions that can be used for timeliness metrics. Although there is much variability among outbreaks, all milestones apply and are important for assessing time intervals between key actions taken.

Using timeliness metrics facilitates consistent measurements and the evaluation of progress over time within a country. Ending Pandemics is working with countries to integrate these milestones into routine surveillance and build them into data dashboards so that they are automatically collected during outbreaks.

PARALLEL SESSION 2
Addressing nosocomial outbreaks

Chair: Abdullah Algwizani, Public Health Authority, Saudi Arabia

RISK FACTORS FOR SUPERSPREADING EVENTS IN HEALTH-CARE FACILITIES

Jaffar Al-Tawfiq, Johns Hopkins Aramco Healthcare, Saudi Arabia

The 2015 MERS-CoV outbreak in the Republic of Korea had high levels of nosocomial transmission and superspreading, with five patients responsible for 83 percent of the total cases. In hospitals with lower levels of transmission, the physical separation of patients was identified as a contributing factor, with other factors such as hospital design, patient flow, health workers' adherence to IPC measures, the use of PPE during aerosol-generating procedures, patient characteristics and social norms (e.g. "medical shopping") all identified as contributing to nosocomial MERS-CoV transmission (Al-Tawfiq and Auwaerter, 2019). More studies are needed to understand superspreading events, strengthen IPC practices and develop targeted control measures to prevent large nosocomial outbreaks.

INFECTION PREVENTION AND CONTROL FOR RESPIRATORY PATHOGENS, INCLUDING MERS-COV

Majed Alshomrani, National Guard Health Affairs, Saudi Arabia

A study of MERS-CoV outbreaks in health-care settings in Jeddah and Riyadh between 2014 and 2015 showed that rapidly identifying and isolating cases and avoiding high-risk contacts limited sustained transmission. Additional IPC measures for droplet and airborne transmission have been introduced in hospitals, including training staff in hand hygiene, PPE use, acute respiratory illness identification and response, N95 fit testing, cleaning and disinfection, and waste segregation. Structural changes have also been necessary, such as changing behaviour through dedicated acute respiratory illness triaging, waiting and clinical areas, with guidelines, policies and information resources developed to support such changes. The effort needed to build and strengthen capacity for respiratory pathogen IPC measures within hospitals is significant and should be supported with competent human resources, physical structures and logistics management, clear policies and strong leadership.

IMPROVEMENTS IN INFECTION PREVENTION AND CONTROL FOLLOWING NOSOCOMIAL OUTBREAKS

Tong Ryong Jung, Korea Disease Control and Prevention Agency (KDCA), Republic of Korea

A lot of the success of the Republic of Korea's COVID-19 response to date is largely due to the lessons learned from the 2015 MERS-CoV outbreak. At the time, the Government of the Republic of Korea evaluated the response to the MERS-CoV outbreak and identified five main gaps: 1) delayed early response due to insufficient preparedness; 2) insufficient infrastructure for a large-scale outbreak of emerging infections; 3) weak governance at the central and provincial levels; 4) infection risks in hospital settings; and 5) a lack of effective and transparent communication.

The national preparedness and response system was subsequently developed to strengthen the country's preparedness and response to future threats. Investments were made in improving infrastructure, such as designated infectious disease hospitals with specifically trained staff, with the number of airborne infection isolation rooms tripled and emerging infectious disease R&D increased. IPC measures were strengthened through legal and financial mechanisms, improved emergency room conditions and changes to hospital visitation practices. The Republic of Korea also improved its response capacity through the introduction of emergency use authorization for diagnostics during outbreaks, huge expansions in the number of Epidemic Intelligence Service officers and rapid response teams, and improved governance with guidelines for central and local governments on infectious disease control. These investments have helped support the country's preparedness for and response to COVID-19.

ENVIRONMENTAL PERSISTENCE OF MERS-COV

Neeltje van Doremalen, National Institutes of Health, United States of America

Laboratory studies have been conducted on diluted respiratory viruses (MERS-CoV, SARS-CoV, SARS-CoV-2 and influenza) to assess and compare their stability on different surfaces and in different environmental conditions. MERS-CoV was found to be stable on plastic and stainless steel in indoor conditions, as opposed to influenza virus, though increasing heat and relative humidity reduces its stability. Increases in relative humidity decreases MERS-CoV viability in aerosols, unlike influenza virus (van Doremalen, Bushmaker and Munster, 2013). There are no major differences in surface or aerosol stability between different MERS-CoV isolates or clades, except for a camel isolate from Saudi Arabia. SARS-CoV-1 and SARS-CoV-2 performed similarly in these assays, with copper and silver reducing the stability of both coronaviruses (van Doremalen *et al.*, 2020a, 2021). This evidence suggests that differences in transmission between MERS-CoV and both SARS-CoV and SARS-CoV-2 are unlikely due to the environmental stability of the virus.

PLENARY SESSION 3
How has COVID-19 shifted our thinking?

HOW WILL COVID-19 CHANGE OUR WORK?

Video presentation
MERS-CoV highlighted the importance and risk of the animal-human interface and has been instrumental in bringing a collaborative, multisectoral, One Health approach to emerging infectious disease prevention and control. COVID-19 has resulted in many developments that now need to be leveraged for other diseases, including MERS-CoV. These include improved diagnostics and testing strategies, genomic sequencing, clinical management, risk communication and education for communities and the tackling of misinformation.

Coronavirus immunity appears to be highly specific, with viral mutations and immune escape posing challenges to vaccine development. Vaccine approaches for coronaviruses should therefore focus on inducing immunity across viral subfamilies. COVID-19 has proven how quickly vaccine candidates can in fact be developed.

PANEL DISCUSSION: HOW DO WE UTILIZE THIS MOMENT TO IMPROVE GENOMIC SEQUENCING FOR CORONAVIRUSES WORLDWIDE?

Facilitator: Amal Barakat, WHO EMRO
Ahmad Albarag, Public Health Authority, Saudi Arabia; Christian Drosten, Charité, Germany; Eun-Jin Kim, KDCA, Republic of Korea; Marion Koopmans, Erasmus University Medical Centre, the Netherlands; Supaporn Wacharapluesadee, King Chulalongkorn Memorial Hospital, Thailand; Stefan Weber, United Arab Emirates

COVID-19 has highlighted the contributions of genomics to public health responses, with large investments in technical and analytical capacity resulting in the substantial expansion of genomic activities. For MERS-CoV, the use of genomics should be targeted to the most relevant questions, and special focus should in particular be given to One Health problems. This includes, for example, understanding and monitoring zoonotic MERS-CoV fitness and transmission dynamics, especially among clades in Africa and the Arabian Peninsula. Genomic sequencing must be linked to public health actions, with requirements and use cases defined to ensure the appropriate and efficient usage of resources. Biological data from traditional laboratory approaches and human, animal and environmental metadata should support genomics results to understand their biological and clinical relevance. Integrating these data will require the establishment of a large database and data-sharing across One Health sectors.

Capacity to perform genomic sequencing must be strengthened, including the necessary information technology infrastructure, computing and bioinformatics capabilities. National repositories for data-sequencing could feed into international repositories. Similarly, strong data structures, policies and governance must be in place to ensure data quality and facilitate data-sharing, with the capacity of regional laboratories also strengthened through laboratory networks and training. Reagents could be made more affordable through technology transfers.

At present, whole-genome sequencing of coronaviruses in bats is difficult due to technical, logistical and biological challenges. Building genomic capacity has financial implications that should ideally be driven by the region and with complementary support from international organizations. Private sector funding, especially from industries that benefit from genomic data, such as vaccine development companies, could also support these efforts.

PARALLEL SESSION 3
Communities and communications

Chair: Ahmed El Idrissi, FAO

PANEL DISCUSSION: CAMELS, COMMUNITIES AND ZOONOTIC RISKS

Bhanu Chaudhary, United Arab Emirates University, United Arab Emirates; Mindy Frost, WHO; Rachel James, Coordinator, Collective Service Risk Communication and Community Engagement (RCCE) Eastern and Southern African Office; Roba B. Jilo, Tufts University, United States of America; Mohamed Nour, Ministry of Public Health, Qatar

Community engagement is important for controlling MERS-CoV. Focus should therefore be placed on building MERS-CoV awareness among the most-at-risk populations in Africa and the Arabian Peninsula and empowering them in prevention. To be effective, community interventions should be appropriate to their context and co-developed with members of the community (Collective Service, 2022; Collective Service, IOM and UNICEF, 2021; WHO, 2021). The integration of social sciences and anthropology with traditional public health approaches can support the identification of effective solutions for community-level problems. Engaging the right partners to facilitate community involvement is also important, particularly community leaders. Good risk communication in hard-to-access communities requires first understanding their social structure, dynamics, motivations and priorities, and then developing plans within this framework.

There is a need to engage communities in One Health research and to encourage regional collaboration in this approach. Regional One Health hubs should include awareness-raising, risk communication and community engagement activities that are appropriate for MERS-CoV and other zoonotic diseases.

PARALLEL SESSION 4
Advancing research and development

Chair: Hanan Balkhy, WHO

OVERVIEW OF THE RESEARCH AND DEVELOPMENT AGENDA

Bart Haagmans, Erasmus University Medical Centre, the Netherlands

Key focuses of the road map for MERS-CoV research and product development include a coronavirus surveillance network, understanding MERS-CoV pathogenesis and improved diagnostics, vaccines and therapeutics. Any update to the road map will need to incorporate the latest MERS-CoV research, as well as knowledge gained from the COVID-19 pandemic. Diagnostics R&D should focus on point-of-care testing, access to clinical specimens, the establishment of international reference standards and improvements to MERS-CoV genomic sequencing.

Building on the success of therapeutic antibodies for SARS-CoV-2, a variety of MERS-CoV-specific antibodies show promise, including monoclonals that target the receptor binding and S2 domains of the MERS-CoV spike protein and polyclonal antibodies developed in cattle. Therapeutics research should consider combined approaches that target the virus and host immune response, including antivirals and cytokines that have been shown to have an effect against MERS-CoV.

MERS-CoV vaccine development has been guided by WHO's target product profiles, indicating the vaccine's use in both humans and camels. Three candidates have completed phase 1 trials. Moving forwards, appropriate animal and in vitro models for the testing of diagnostics, therapeutics and vaccines should be determined, especially given the sporadic nature of human cases. Funding MERS-CoV R&D in the context of a small commercial market must also be considered.

WHERE ARE WE WITH THERAPEUTICS FOR MERS-COV? HOW HAS THE WORK FOR SARS-COV-2 ADVANCED PROGRESS FOR MERS-COV?

Yaseen Arabi, King Abdullah International Medical Research Center (KAIMRC), Saudi Arabia

The MERS-CoV Infection Treated with a Combination of Lopinavir–Ritonavir and Interferon Beta-1b (MIRACLE) trial investigated the efficacy of a combination of recombinant IFN-β1b and lopinavir–ritonavir in MERS-CoV patients using a randomized, adaptive, double-blind, placebo-controlled trial conducted across several hospitals in multiple cities. Trial enrolment started in 2016, with the first interim analysis in 2019 indicating that 114 patients were necessary to determine an effect. The trial was stopped early when an interim analysis demonstrated an absolute risk reduction of 19 percent in mortality within 90 days, which increased to 80 percent if patients were treated within seven days of symptom onset (Arabi *et al*., 2020). More efficient and flexible trial designs for MERS-CoV therapeutics are needed that have the ability to test multiple interventions simultaneously, adapt sample sizes, introduce and drop interventions and learn from each enrolled patient.

Building on the clinical management experience from both MERS-CoV and COVID-19, a better understanding of pathophysiology can guide further advances. Early antibody responses with MERS-CoV are associated with lower mortality, suggesting that, as in the case of COVID-19, antibody-based therapeutics could be helpful for MERS-CoV if given early. A dysregulated immune response is a feature of COVID-19, while in MERS-CoV patients, a high proinflammatory response is associated with a worse outcome. Baseline immune profiles may influence therapeutics efficacy.

UPDATE ON MERS-COV VACCINATION FOR DROMEDARY CAMELS

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A MERS-CoV infection model that mixes naturally infected seropositive dromedary camels with seronegative dromedary camels has been established to understand infection dynamics. It shows that MERS-CoV infection in camels is short, lasting no more than two weeks, and is mostly subclinical (Alharbi *et al*., 2020). The model has also been used to test the ChAdOx1 MERS vaccine and shows that the vaccine is immunogenic, upregulates type I and II interferons and B-cell pathways and results in complete and partial protection in both seronegative and seropositive camels. The vaccine has also been shown to reduce viral shedding and clinical signs of infection in camels. Age and/or serostatus appear to influence the vaccine's efficacy, as seronegative camels younger than a year do not have immune responses after one dose of the vaccine (Alharbi *et al*., 2019; Hala *et al*., 2021). Age may also explain differing levels of seropositivity found in studies with camels from different Arabian and African locations (El-Kafrawy *et al*., 2019). More research focus is now needed on camel-to-human transmission, given that exposure greatly exceeds human infection (Aljasim *et al*., 2020).

The biggest challenge for further dromedary camel vaccine development is currently the lack of a feasible market, and will therefore likely require government subsidization and mandates. Furthermore, if a vaccine were to become commercially available, the issues around acceptance, adoption, distribution, vaccination objectives and strategies, and implications for trade, movement and livelihoods would be complex to navigate.

CORONAVIRUS RESEARCH AND INNOVATION NETWORK

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The UK International Coronavirus Network (UK-ICN)[2] is a four-year project, funded by the UK Biotechnology and Biological Sciences Research Council and the UK Department of Environment, Food and Rural Affairs. It was developed to

[2] See www.liverpool.ac.uk/health-and-life-sciences/research/uk-international-coronavirus-network/.

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be a One Health network for coronavirus research following the observation that the information known from animal coronavirus research was not being used in the COVID-19 response. This network partners with other networks, such as the Global Strategic Alliances for the Coordination of Research on the Major Infectious Diseases of Animals and Zoonoses (STAR-IDAZ) International Research Consortium, for pan-coronavirus research. Its meetings and workshops focus on: 1) One Health and zoonoses; 2) surveillance: detection and characterization; 3) countermeasures and interventions; 4) behaviour and social policy; and 5) SARS-CoV-3 and the future. The UK-ICN plans to hold regional meetings in 2022. One of its key activities will be to support early career researchers, including through providing travel bursaries and funding for small collaborative research grants.

Meeting closure

Chair: Gounalan Pavade, WOAH

CLOSING REMARKS

Gounalan Pavade, WOAH; Maria Van Kerkhove, WHO; Sophie von Dobschuetz, FAO

MERS-CoV remains a high-threat priority pathogen, meaning continued vigilance is essential. Lessons learned from the MERS-CoV response were crucial in the global COVID-19 response, particularly in terms of technical guidance, research protocols, scientific networks and the application of a One Health approach. Anti-science sentiment and misinformation have been major challenges during the pandemic. It will therefore be important to continue making scientific progress, not only for COVID-19, but for other diseases, including MERS-CoV.

There is increased need for MERS-CoV surveillance and reporting in camels and humans, with renewed emphasis across the Middle East and a particular focus in Africa. Surveillance for MERS-CoV in humans should be integrated into surveillance for respiratory pathogens in MERS-CoV-affected regions and at-risk areas for importation, and One Health interventions should be planned and strengthened with consideration given to community priorities and needs. The feasibility of camel vaccines must be re-evaluated and advocated for, and it will be necessary for FAO to conduct studies to explore the acceptance of camel vaccination in its project countries (Egypt, Ethiopia, Jordan and Kenya).

The COVID-19 pandemic has demonstrated unprecedented mobilization of the public health and research community through the collaborative and high-quality work of thousands of researchers and research institutions. The scientific achievements of the pandemic must be leveraged for other diseases, including MERS-CoV. On behalf of their members, WHO, FAO and WOAH are committed to facilitating this multisectoral collaboration.

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