How to sample surfaces in health-care settings for Middle East respiratory syndrome coronavirus

Protocol, tools and implementation guidance

Unity Studies

World Health Organization

How to sample surfaces in health-care settings for Middle East respiratory syndrome coronavirus

Protocol, tools and implementation guidance

World Health Organization

How to sample surfaces in health-care settings for Middle East respiratory syndrome coronavirus: protocol, tools and implementation guidance

ISBN 978-92-4-010013-8 (electronic version)
ISBN 978-92-4-010014-5 (print version)

Suggested citation. How to sample surfaces in health-care settings for Middle East respiratory syndrome coronavirus: protocol, tools and implementation guidance. Geneva: World Health Organization; 2024.
Licence: CC BY-NC-SA 3.0 IGO.

Cataloguing-in-Publication (CIP) data. CIP data are available at https://iris.who.int/.

Design and layout by Lushomo.

Contents

List of tables

Acknowledgements

The development of this document was led by Abdullah Al-Sayafi and Sophie von Dobschuetz, at the World Health Organization (WHO) Headquarters (HQ), Emerging Diseases and Zoonoses Unit, Epidemic and Pandemic Prevention and Preparedness Department in Geneva, Switzerland, as well as by Anna Funk (University of Calgary, Calgary, Canada).

The development of this document was supported by:

- Ahmed Ali Alghazal (Prince Saud Bin Jalawy Hospital, Ministry of Health, Al-Hasa, Saudi Arabia), Elmoubashar Farag (Ministry of Public Health, Doha, Qatar), Bart Haagmans (Erasmus Medical Center, Rotterdam, Netherlands [Kingdom of the]), Mazharul Islam (Ministry of Municipality, Doha, Qatar), Euzebiusz Jamrozik (University of Oxford, Oxford, United Kingdom of Great Britain and Northern Ireland), Ruth McCabe (University of Oxford, Oxford and Imperial College London, London, United Kingdom), Joseph Sriyal Malik Peiris (the University of Hong Kong, Hong Kong Special Administrative Region, China), Reina Sikkema (Erasmus Medical Center, Rotterdam, Netherlands [Kingdom of the])

- several colleagues from WHO including: Hala Abou El Naja (WHO Regional Office for the Eastern Mediterranean, Cairo, Egypt), Isabel Bergeri (Epidemic and Pandemic Prevention and Preparedness Department, HQ), Nicki Boddington (Epidemic and Pandemic Prevention and Preparedness Department, HQ), Alice Simniceanu (Epidemic and Pandemic Prevention and Preparedness Department, HQ), Lorenzo Subissi (Epidemic and Pandemic Prevention and Preparedness Department, HQ), Maria Van Kerkhove (Epidemic and Pandemic Prevention and Preparedness Department, HQ)

All external contributors submitted to WHO a declaration of interest disclosing potential conflicts of interest that might affect, or might reasonably be perceived to affect, their objectivity and independence in relation to the subject matter of the guidance. WHO reviewed each of those and concluded that none could give rise to a potential or reasonably perceived conflict of interest related to the subjects covered by the guidance.

Thanks are due to the United States Agency for International Development (USAID) for providing financial support.

This protocol was initially conceived at a meeting on the Environmental Contamination Studies of MERS-CoV in Health Care Settings co-hosted by WHO and The University of Hong Kong on 13-14 March 2017. The participants of that meeting are listed at the end of the document. In 2017, this protocol was developed by Pieter Fraaij, Bart Haagmans, Marion Koopmans, Chantal Reusken and Reina Sikkema from Erasmus Medical Center, Rotterdam, the Netherlands, with input and reviews provided by WHO and

a large number of respiratory disease experts. In 2017 this work was supported by the European Commission's H2020 program under contract number 643476 and US Agency for International Development (USAID). Participants 2017 Hong Kong meeting: Ada Al-Qunaibet (King Abdullah International Medical Research Center, Saudi Arabia), Ahmad Ashshi (University of Umm Al-Qura, Saudi Arabia), Hong Chen (Department of Health, Hong Kong Special Administrative Region, People's Republic of China), Young-Ki Choi Chungbuk National University, Republic of Korea), Elmoubasher Farag (Ministry of Public Health, Qatar), Keiji Fukuda (The University of Hong Kong, Hong Kong Special Administrative Region, People's Republic of China), Bart Haagmans (Erasmus Medical Center, the Netherlands), David Hui (The Chinese University of Hong Kong, Hong Kong Special Administrative Region, People's Republic of China), Sung-Han Kim (Asan Medical Center, Republic of Korea), Sung-Soon Kim (Korea Centers for Disease Control and Prevention, Republic of Korea), Yae-Jean Kim (Samsung Medical Center, Sungkyunkwan University, Republic of Korea), Yuguo Li (The University of Hong Kong, Hong Kong Special Administrative Region, People's Republic of China), Vincent Munster (National Institute of Allergy and Infectious Diseases, United States of America), Myoung-don Oh (Seoul National University, Republic of Korea), Malik Peiris (The University of Hong Kong, Hong Kong Special Administrative Region, People's Republic of China), Maria Van Kerkhove (World Health Organization, Switzerland), Jeong-Sun Yang (Korea Centers for Disease Control and Prevention, Republic of Korea), Hui-Ling Yen (The University of Hong Kong, Hong Kong Special Administrative Region, People's Republic of China). Reviewers of the 2017 version of this protocol: Maria Van Kerkhove (WHO/HQ), Rebecca Grant (WHO/HQ), Peter Ben Embarek (WHO/HQ), Christian Drosten (GER/Charite), Malik Peiris (The University of Hong Kong, Hong Kong Special Administrative Region, People's Republic of China), Hui-Ling Yen (The University of Hong Kong, Hong Kong Special Administrative Region, People's Republic of China), Susan I. Gerber (United States Centers of Disease Control and Prevention, United States of America), Matthew Arduino (United States Centers of Disease Control and Prevention, United States of America), Judith Noble-Wang (United States Centers of Disease Control and Prevention, United States of America), Laura J. Rose (United States Centers of Disease Control and Prevention, United States of America), John Watson (United States Centers of Disease Control and Prevention, United States of America), Yaseen Arabi (King Saud Bin Abdulaziz University for Health Sciences, Saudi Arabia).

Background

Middle East respiratory syndrome coronavirus (MERS-CoV), which was first identified in 2012, is considered an emerging virus. The emergence of a new virus means that understanding transmission patterns, severity, clinical features and risk factors for infection are limited. To address these unknowns, WHO has provided a number of protocols for MERS-CoV investigations. Data collected using these investigation protocols will be critical to refine recommendations for case definitions and surveillance, characterize key epidemiological features of MERS-CoV, help understand the geographical extent of MERS-CoV, its severity, the spectrum of the disease and its impact on the community; and to inform guidance for application of countermeasures such as case isolation and contact tracing. These protocols are designed to rapidly and systematically collect and share data in a format that facilitates comparison across different settings globally.

They are available on the WHO website here: https://www.who.int/initiatives/mers-cov-investigations-and-studies

MERS-CoV investigation and study protocols, tools and implementation guidance currently available include:

How to conduct surveillance and investigations of human infection with Middle East respiratory syndrome coronavirus using WHO's Investigations and Studies (Unity Studies 2.0) protocols;

How to investigate the first few X cases and contacts of human infection with Middle East respiratory syndrome coronavirus;

How to conduct a case-control study to assess the potential risk factors related to human illness caused by Middle East respiratory syndrome coronavirus;

How to conduct a cohort study to assess the potential risk factors of Middle East respiratory syndrome coronavirus infection among health and care workers in a health-care setting;

How to sample surfaces in health-care settings for Middle East respiratory syndrome coronavirus; and

How to conduct a cross-sectional study of Middle East respiratory syndrome coronavirus infection in populations occupationally exposed to dromedary camels.

Please contact MERSHQ@who.int for further information.

All of the WHO protocols for MERS-CoV are available on the WHO website together with technical guidance documents.

This protocol is an update of the previously published interim guidance entitled, Surface sampling of MERS-CoV in health care settings: A practical "how to" protocol for health care and public health professionals – Version June 2019 to reflect current scientific knowledge about MERS-CoV, and the results and experiences of similar studies conducted in several countries. The protocol was also adapted from and supplemented by protocols developed and used during the COVID-19 pandemic through WHO's Investigations and Studies (Unity Studies): a standardized preparedness framework for an effective and proportionate response, as well as experiences and lessons learned during the COVID-19 pandemic.

Protocol summary

Sampling surfaces in healthcare settings for MERS-CoV	
Study population	Not applicable
Objectives, potential output and analysis	1) To assess the extent and persistence of environmental surface contamination with MERS-CoV 2) To determine possible routes of onwards MERS-CoV transmission within healthcare settings
Study design	Not applicable
Timing of the investigation	As soon as possible after an individual positive for MERS-CoV has been admitted to and/or visited a health-care facility
Study duration	Up to 7 days *after* a MERS-CoV positive patient has left the sampling location
Information and specimens to be obtained	**Data:** Detailed map of the health-care facility. If not otherwise collected: demographic and clinical information about the MERS-CoV positive patient. **Specimens:** Daily environmental samples of high-touch surfaces linked to where a MERS-CoV infected person is receiving care in a healthcare setting

Implementation tips are provided in boxes throughout the document.
This is a protocol template – the user should read through the template and guidance and then modify (and make choices about) the methods according to the local context in which this study will be carried out. If being adapted for use as the investigation protocol, the user should remove any non-relevant sections and modify the language appropriately (e.g. Change the phrase "Investigators should create a detailed map(s) of the facility; within this map(s) and its legend(s), the following details should be included:…" to "We have created a detailed map of facility X, where the MERS-CoV positive patient was identified on [date], this map includes the following details:…"). Background information referenced in this document should be checked for updates by investigators at the time of protocol implementation.

1. Scientific background and rationale

In late 2012, a novel coronavirus was identified for the first time in a resident of Saudi Arabia *(1)*. As of April 2024, the virus, now known as Middle East respiratory syndrome coronavirus (MERS-CoV), has caused over 2600 reported laboratory-confirmed cases of human infection *(2)*. MERS-CoV is a zoonotic virus and dromedary camels are the single known maintenance host and primary reservoir *(3-8)*, but the route of transmission to humans is unknown *(8)*.

Although MERS-CoV appears to be inefficient at transmitting between humans in the general population, human-to-human transmission has occurred and been documented in several clusters in healthcare facilities in Jordan, Saudi Arabia, the Republic of Korea and the United Arab Emirates *(9)*; occasionally, this has resulted in significantly large outbreaks *(10-13)*. Additionally, one instance of nosocomial transmission was documented in France in 2013 *(14).* Since 2020, instances of nosocomial transmission have only been documented in Saudi Arabia *(2, 15)*. Person-to-person transmission has also been identified through investigations of clusters of cases in households and other settings *(2, 15-24)*. Historically, the majority of all reported human MERS-CoV infections have occurred through human-to-human transmission in healthcare settings, and as of November 2022, 17% of human MERS cases were in health and care workers *(2)*. However, in recent years most cases reported have been sporadic or primary (with a reported link to camel exposure or their products). Our understanding of the mechanisms of transmission of MERS-CoV in healthcare settings remains limited. Factors associated with amplified human-to-human transmission in healthcare facilities have included poor infection prevention and control (IPC) compliance by health and care workers *(9, 25)*. Adherence to IPC procedures, and rapid identification and isolation of individuals positive for MERS-CoV has limited transmission in some healthcare settings *(8, 9)*.

During past MERS-CoV nosocomial outbreaks, a number of environmental contamination studies evaluating MERS-CoV persistence on surfaces and other mediums in healthcare settings have been carried out in affected hospitals *(25-28)*. In these studies, MERS-CoV ribonucleic acid (RNA) was detected on various medical devices, in ventilation equipment, on door-knobs, on surfaces in anterooms and in other areas, up to 28 days after the patient's initial symptom onset and in some cases *(26, 27)*. MERS-CoV RNA was also been retrieved from air samples in a hospital and in a dromedary camel barn *(28, 29)*. Additionally, some laboratory studies into environmental contamination with infectious MERS-CoV and/or MERS-CoV RNA outside healthcare settings have also been published *(30, 31)*. Further information comes from simulations and models, which also examine the possible effects of IPC measures (or lack of) on spread of MERS-CoV in hospitals *(32-34)*. In laboratory-based studies, MERS-CoV has been found to remain stable on stainless steel and polypropylene (plastic) surfaces for up to 48 hours (depending on environmental conditions), as well as in aerosolized form for up to 180 min *(30, 31)*. The viability of MERS-CoV on fomites such as plastic and stainless steel surfaces, as well as in aerosolized form, was decreased with increasing heat and humidity *(30)*. Stability of MERS-CoV was significantly lower, with increased decay by time, for copper and silver surfaces. There is some evidence to suggest that different MERS-CoV strains, taken from distinct geographical locations, have varying surface stability characteristics *(31)*. While environmental contamination of MERS-CoV in several settings has been confirmed, our

understanding of the extent of viable MERS-CoV virus on surfaces in hospital settings, and the risk which this poses for human exposure, is inconsistent.

Results from the studies that were initially available on the topic of environmental sampling of MERS-CoV highlighted the need for standardization of methods. Therefore, this practical "how to" protocol was initially drafted in 2017 to enable systematic collection, storage and analysis of the appropriate samples to evaluate (viable) MERS-CoV virus persistence in healthcare settings. As of 2024, this document has been updated, and studies addressing the role of environmental contamination of MERS-CoV continue to be essential to inform recommendations to prevent and control human infection with MERS-CoV.

1.1 Study objectives

1.1.1 Primary objectives

The primary objectives (overall aims) of this investigation are to:

1. Assess the extent of (viable) MERS-CoV surface contamination and its persistence, on various surfaces within a healthcare setting in which a patient infected with MERS-CoV is currently being treated
2. Identify surfaces which may play a role in onwards transmission of MERS-CoV in healthcare settings through assessment of surface contamination in relation to information on patient care, handling and movement

1.1.2 Secondary objectives

This investigation provides the opportunity to inform and evaluate secondary objectives such as, but not limited to:

3. Challenging the viability of MERS-CoV on inanimate surfaces under different environmental conditions
4. Characterize the sequence diversity of MERS-CoV in environmental samples

Implementation tip Assessing the contribution of environmental contamination in human-to-human transmission of MERS-CoV is only possible if it is done as part of a comprehensive outbreak investigation and if information obtained by environmental studies is combined with the results of epidemiological, laboratory and sequence data from MERS patient investigations. See the Background section on page vii for information about, and links to, other MERS-CoV investigations.

2. Methods

2.1 Study design, timing and duration

Design. This is an environmental sampling study of surfaces and other fomites in areas of healthcare facilities where a person with laboratory-confirmed MERS-CoV infection is receiving care. This investigation and its results should be linked with other investigations related to this confirmed MERS case: see for example WHO templates for First Few X cases and contacts (FFX) investigation for MERS-CoV and Case-control study to assess potential risk factors related to human illness caused by MERS-CoV. Environmental sampling data provide supplementary information, which needs to be interpreted in the context of the outbreak dynamics and characteristics, patient sampling and sequencing and testing of contacts.

Timing. This investigation should ideally be started as soon as possible after a confirmed MERS case is identified in a health-care facility. It should ideally be started while they are still admitted or present in the health-care facility.

Duration. Daily environmental sampling should be conducted (see 'timing' above) until up to 7 days after a MERS-CoV positive patient has been in contact with each sampling location.

2.2 Study Setting

This study takes place in a hospital or other health-care facility type (e.g. clinic, community healthcare centre) where a person with confirmed MERS-CoV is receiving care.

Implementation tip This protocol has been written to investigate MERS-CoV surface contamination in healthcare settings, however, there may be other environments where investigation of surface contamination with MERS-CoV is of interest, for example in a dromedary camel barn or abattoir or in the home(s) of persons included in a MERS cluster. This protocol can be adapted for use in other environments – if you would like support with this, please reach out to MERSHQ@who.int.

In order to link data from environmental sampling to outbreak investigations, and to identify risk factors for environmental contamination and for exposure of other individuals, it is important to collect extensive background information on the health-care facility and the patient's movement(s) within it. Investigators should create a detailed map(s) of the facility; within this map(s) and its legend(s), the following details should be included:

- Detailed hospital and patient room layout, including features such as: area function (Emergency Department, ward, Intensive Care Unit), placement of major furniture and beds, hospital equipment and ventilation inlets and outlets and the location of other MERS patient(s).

- Routing and movement(s) of the MERS patient and/or the locations that the patient visited previous to being isolated (e.g. elevator, hall, waiting room, X-ray room). Each room where the patient stayed should be noted, with a list of activities conducted there and an estimate of the amount of time spent. This information should be known when developing the sampling plan.

- Health and care worker routes, patients treated and treatment procedures in the affected hospital location. For each HCW, the rooms and patients that were visited and treatments that were executed, including dates and time, should be logged.

- Timing and details of factors that could influence the outcomes of environmental sampling (e.g. aerosol generating procedures, PPE worn by both patient and HCW, cleaning and disinfection activities, temperature and humidity in sampling locations) → these factors should be collected and noted on the generated maps in real-time during the sampling time period (they are not, per se 'background information'), and so will be discussed further in section 2.4.

2.3 Data Collection for MERS Case (only if not otherwise conducted)

As mentioned, environmental sampling should be conducted as part of a comprehensive MERS case or outbreak investigation (see the Background section on page vii) and combined with results from those studies. All patient data that is necessary to collect in healthcare settings is outlined in those protocols.

Only in the instance that the confirmed MERS case, that is the focus of this investigation, has **not** had any other data collected as part of other investigations, they should give informed consent (see section 2.6.1) and be administered the questionnaire (Annex 1). This form contains questions relating to specific patient data that is essential for the interpretation of this environmental sampling investigation.

2.4 Environmental Sampling Collection Sites

The recommended sampling sites in Table 1 are based on 1) possible MERS-CoV transmission routes and 2) current literature on high-touch surfaces *(35-38)*. Furthermore, the standardization of sampling sites in MERS-CoV surface sampling studies in healthcare facilities will improve the possibilities of comparing the results of multiple studies. Which sampling sites are tested, and the results of these tests, should be entered into a standardized

form; a template of this form, to be adjusted by investigators according to the context of each investigation, is given as the 'Site sampling form' in Annex 2.

Using the detailed health-care facility maps developed as part of section 2.2, and the recommendations seen in Table 1, investigators should decide on the sampling sites that will be tested as part of this investigation. As every health-care facility has a different layout, the sampling scheme should be adapted to reflect the layout of each health-care facility involved in this investigation. Investigators should note down proposed sampling sites as an overlay (or additional map) to their detailed facility map.

Implementation tip Patients who have tested positive for MERS-CoV should be placed immediately under isolation and if applicable, moved to a separate room. However, prior to the patient's MERS-CoV positive test result, they may have already visited and contaminated other areas in the health-care facility. Therefore, it is important to trace back patient movements during their visit and/or admission in the hospital and sample all the areas the MERS patient visited during their hospital stay (see guidance for creating a map of the health-care facility in section 2.2).

Table 1. Recommended sampling sites by health-care facility location *(26, 28, 39)*

Possible source of MERS-CoV hospital exposure	Essential sampling sites		Other sampling sites	
1. Patient (entry) routing	Ambulance	Medic bag handle, inside of blood pressure cuff, wall next to the patient stretcher	Ambulance	Front of defibrillator, handlebar ambulance ceiling,
	Entrance	Ventilation exits or air purifier filters, guardrails	Entrance, corridor, waiting room	Doorknob, light switch, sink, faucet handles
	Corridor	Ventilation exits or air purifier filters, guardrails	Elevator	Buttons, ventilation exits or air purifier filters, guardrails
	Waiting room	Ventilation exits or air purifier filters, guardrails	X-ray room	Ventilation exits or air purifier filters, doorknob, light switch, X-ray table, sink, faucet handles
2. Hospital staff	Staff room	Doorknob, keyboard, clothes, ventilation exits or air purifier filters	Staff room, anteroom	Sink, faucet handles, desk and/or table, light switch, chairs
	Ante room	Doorknob, light switch, ventilation exits or air purifier filters	Patient room	Monitor controls, monitor touch screen, charts

Possible source of MERS-CoV hospital exposure	Essential sampling sites		Other sampling sites	
3. Patient handling and care/patient virus excretion and risk procedures	Patient room	Doorknob, bed rails, bedside table, bed controller, call button, floor (<1meter from the patient, 2m, 3m, etc.), tubing, masks and filters of aerosol generating procedures, control panels	Patient room	Bedding, IV pole, telephone, chair, curtain, patient clothing, light switch, stethoscope, thermometer, hand soap dispenser, garbage bin, cup, curtains, oxygen flow meter
	Patient bathroom	Doorknob, faucet handles, sink, toilet and/or bed pan	Patient bathroom	Light switch, bed pan cleaner, guard rails
4. Air flow	Patient room	Ventilation exits or air purifier filters	Patient room	Wall (<1meter from the patient, 2m, 3m, etc. if possible)
	Patient bathroom	Ventilation exits or air purifier filters	Patient bathroom	Wall (<1meter from the patient, 2m, 3m, etc. if possible)

Implementation tip Air sampling has not been included in this protocol. The current protocol addresses surface sampling which can be implemented by most hospitals reporting a MERS case, provided there is sufficient personnel. However, setting up a high quality and reproducible air sampling study with the possibility of culturing the virus would require specialist knowledge, sufficient laboratory facilities, and appropriate equipment. Additionally, a best practice for air sampling is yet to be developed. Currently, there is not enough information available on the best equipment and methodology to sample MERS-CoV from air samples, although this is subject to revision as more information becomes available.

After deciding on environmental sampling sites, investigators should also do an assessment of the timing and details of factors that could influence the outcomes of environmental sampling. These can be added to (as an overlay) existing maps of the health-care facility (as created in section 2.2), or as additional maps, and would include:

- The place, time and duration of aerosol generating procedures should be indicated, including: negative pressure rooms, positive pressure ventilation (bi-level positive airway pressure [BiPAP] and continuous positive airway pressure [CPAP]), endotracheal intubation, high flow nasal cannula, open airway suction, high frequency oscillatory ventilation, tracheostomy, chest physiotherapy, nebulizer treatment, sputum suction and bronchoscopy *(40, 41)*

- The time, frequency and details (e.g. disinfectant) of the cleaning and disinfection activities should be collected for all possible sampling locations

- The temperature and humidity as well as ventilation system (and whether negative pressure is used) of the sampled rooms should be measured and noted daily, as well as the time the bed of the patient was made *(42, 43)*

2.5 Timing and Frequency of Environmental Sampling

Ideally, sampling should take place each day, starting as early as possible after identification of a MERS case and until at least 7 days after the discharge or passing of the patient *(26)*. In case of aerosol generating procedures (listed above), the environment should be sampled before and after (within 1 hour and 24h later) of each procedure. The sampling sites associated with the patient (entry) routing should be sampled in the period from time of suspicion until transfer to a regular ward or ICU *(40)*.

The sampling protocol is recommended to be executed as described above. However, in case of an extensive hospital outbreak, the number of samples and the work that is associated with sampling may be too extensive to handle. In that case, high quality sampling of sufficiently high frequency of the surfaces of a few patients (ideally representing different settings within the facility) has priority over sampling all patients involved in the outbreak.

Implementation tip Patients in intensive care units (ICU) may remain hospitalized for extended periods of time and, as such, daily sampling may not be feasible, particularly if there are multiple MERS cases within the same health-care facility. Feasibility and the outbreak context will determine the frequency and duration of repeated sampling.

2.6 Environmental Sample Collection and Testing

2.6.1 Environmental sample collection

Environmental samples need to be taken using a swab with a synthetic tip and a plastic shaft *(25-28, 30, 44)*. The swab specimen collection vials should contain 1 to 3 ml of viral transport medium (e.g. protein stabilizer, antibiotics and buffer solution) including neutralizing buffer to counteract the effects of any residual disinfectant (e.g. Tween 80). Viral transport medium (VTM) is required for virus isolation. However, viral transport medium is not always efficient in case of long shipping times, uncontrolled storage temperature and minute virus concentrations. The use of chaotropic lysis buffers will stabilize viral genomes which is recommended in situations in which storage and transport conditions are not optimal and concentrations of viable virus are expected to be low.

The first step of the sampling procedure is to perform hand hygiene (see *WHO guidelines on hand hygiene in health care for more information)(45)* either by washing with water and soap or using an alcohol-based hand rub, followed by putting on sterile, non-powdered nitrile or vinyl examination gloves as part of standard personal protective equipment

(PPE) and clothing. Then, remove the swab from the package. Wet the swab with VTM. When applying pressure with the wet swab onto the surface, swab in a "z" pattern in three directions (horizontally, vertically and diagonally). Do this for an area of approximately 10cm x 10cm. Avoid letting the swab dry completely. To increase the positive predictive value of the environmental sampling process, each sampling area may require multiple swabs. Controlling for, or standardizing, for the area size is helpful if you want to eventually compare the copy numbers detected in different surface samples (e.g. high-touch vs low-touch surfaces).

After labelling the vial, place in a self-sealing bag and clean the outside of the sealed bag with a 60 to 80% ethanol, 80% isopropyl alcohol or 5% hypochlorite solution just prior to leaving the contaminated area. Then, place the cleaned sealed bag in another unused similar self-sealing bag. This should be followed by hand hygiene after the gloves are removed.

In each sampling round, a set of control samples also need to be collected. The first set of control samples are handled in the same way as the environmental samples from the potentially contaminated area, including opening the package and removing the swab from the tube, but without sampling any surfaces. The second set of control samples remain sealed, but will be shipped, stored and tested with the surface samples, to exclude contamination later on.

Implementation tip If only a single MERS patient is involved, it would be ideal to include an additional control sample from the room of a non-MERS patient within the same health facility. This would strengthen evidence that any positive specimens from the MERS patient's room are true positives, and not laboratory or other contamination. However, inclusion of this additional control will need to be determined by feasibility and the outbreak context.

2.6.2 Labeling, shipment and storage of environmental samples

All those involved in collection and transport of specimens should be trained in safe handling practices and spill decontamination procedures. Appropriate hand hygiene must be conducted alongside appropriate PPE which must be worn by study personnel during the collection of any specimen (see section 2.7.4 for more details). Full details for laboratory testing, specimen collection, biosafety, sample shipment and reporting of test results for MERS-CoV are available on the WHO website *(46)*.

For each sample, the date and time of sampling, exact location and name of person collecting the sample should be noted, as well as the conditions for transportation and the date and time of arrival at the laboratory. At least two aliquots of VTM should be made before the specimens are stored or shipped. One of two aliquots should be stored at -70 °C or -80 °C as soon as possible. Specimen tubes will be stored temporarily on cool packs

carried by the study teams until they can be transported to the laboratory. Specimens should reach the laboratory as soon as possible after collection. If the specimen is not likely to reach the laboratory within 72 hours, specimens should be frozen, preferably at -80 °C, and shipped on dry ice. It is, however, important to avoid repeated freezing and thawing of specimens. The storage of specimens in domestic frost-free freezers should be avoided, owing to their wide temperature fluctuations.

Transport of specimens within national borders should comply with applicable national regulations. International transport of MERS-CoV specimens should follow applicable international regulations as described in the *WHO Guidance on Regulations for the Transport of Infectious Substances 2021-2022 (47).* Appropriate Material Transfer Agreements will need to be signed if samples are to be transported between laboratories within or outside the country.

Implementation tip For labeling and shipping of specimens – it is key to use a basic triple packaging system, correct marking and labeling of specimens and use of appropriate shipping documents. The receiving laboratory should always be contacted before specimens are shipped.

2.6.3 Laboratory evaluations

Any testing for the presence of MERS-CoV should be performed in appropriately equipped laboratories by staff trained in the relevant technical and safety procedures. National guidelines on the laboratory biosafety should be followed in all circumstances. Laboratory guidance and biosafety information for MERS-CoV can be found on the WHO website *(46)*.

Implementation tip It is important to note that negative environmental testing results cannot exclude the presence of virus within the healthcare setting.

Nucleic Acid Amplification Tests (NAAT) including Real-time reverse transcription Polymerase Chain Reaction (rRT-PCR). Three real-time reverse transcription polymerase chain reaction (rRT-PCR) assays for routine detection of MERS-CoV have been developed and their details published *(48-50)*. Currently described tests are an assay targeting upstream of the E protein gene (upE) and assays targeting the open reading frame 1b (ORF 1b) and the open reading frame 1a (ORF 1a). The assay for the upE target is considered highly sensitive and is recommended for screening, with the ORF 1a assay considered of equal sensitivity. The ORF 1b assay is considered less sensitive than the ORF 1a assay. An alternative approach involving two rRT-PCR assays targeting the MERS-CoV nucleocapsid (N) protein gene, which can complement upE and ORF 1a assays for screening and confirmation has also been published. A testing algorithm for investigation of suspected cases of MERS-CoV by Nucleic Acid Amplification Test (NAAT) is

available in the *WHO Guidance on Laboratory testing for Middle East respiratory syndrome coronavirus (MERS-CoV) (46).*

Virus isolation and culture. MERS-CoV isolation and cell culture should only be performed by laboratories with the appropriate experience and biosecurity level 3 (BSL-3) capabilities. Therefore, it is recommended to store and/or ship samples for virus isolation to a (inter)national reference laboratory to perform further analyses. (see section 2.6.2).

Implementation tip A limited number of laboratories have the experience and/or biosecurity capacities for virus isolation and culture. Therefore, collaboration between countries and designated reference laboratories is encouraged. Collaboration is at the discretion of Member States conducting the investigation, but WHO is able to facilitate this collaboration and possible shipment for testing, if required. Please contact MERSHQ@who.int

Genome sequencing. MERS-CoV genome sequencing may provide further details on the genetic relationship of the viruses detected with other viral isolates. A RT- PCR assay for MERS-CoV targeting a 615 bp spike fragment may already provide a phylogenetic clustering of MERS-CoV variants comparable to that of full-length genomes, but this may often be insufficient for detailed molecular epidemiological investigations. Full genomes obtained by NGS using sets of specific primers to amplify the full genome for instance delivers a more detailed picture of genetic differences between viruses. Virus grown in culture may be used as an alternative source of the viral RNA.

Implementation tip Acquired sequence information should be shared and reported via publicly available databases such as GenBank or GISAID; doing so will contribute valuable information to the global effort to understand MERS-CoV epidemiolgy and perform risk assessment.

Material and more detailed methods for MERS-CoV sequencing are described in the following bibliography of further reading:

1. Corman VM, Muller MA, Costabel U, et al. Assays for laboratory confirmation of novel human coronavirus (hCoV-EMC) infections. Euro Surveill 2012;17 (49):20334.
2. Cotten M, Watson SJ, Kellam P, et al. Transmission and evolution of the Middle East respiratory syndrome coronavirus in Saudi Arabia: a descriptive genomic study. Lancet 2013;382:1993-2002.
3. Cotten M, Watson SJ, Zumla AI, et al. Spread, circulation, and evolution of the Middle East respiratory syndrome coronavirus. mBio 2014;5.
4. Smits SL, Raj VS, Pas SD, et al. Reliable typing of MERS-CoV variants with a small genome fragment. J Clin Virol 2015;64:83-7.

2.7 Ethical Considerations

Ethical requirements will vary by country. In all cases, national and local regulations need to be followed. Investigators should confirm the requirements before implementation, which may cover national ethics review only, or national and institutional review.

Implementation tip Ethical approval may be obtained from relevant ethical or institutional review boards in advance using a generic protocol such as this one before an outbreak occurs. If an outbreak occurs, the study design, questionnaires, sampling and consent forms can be modified rapidly to reflect the current outbreak situation. This will likely have to be resubmitted for ethical approval, but if the generic protocol has already been approved, the process is possible that second review may be more rapid, minimizing delays to the start of investigations.

WHO guidelines on ethical issues in public health surveillance can be found on the WHO website *(51)*.

2.7.1 Informed consent (only if patient data not otherwise collected)

Investigations and studies for MERS-CoV and related pathogens may involve testing of samples from humans and animals as well as environmental samples. Collection of samples from humans typically requires individual consent (although not necessarily formal informed consent). However, there are no well-established ethical norms for collection of samples from animals and environments.

Examples of environmental[1] testing may include collection of samples from hospital rooms of patients admitted with (suspected, probable or confirmed) MERS-CoV; such testing will typically be governed by local public health and institutional policies. More complex examples may include collection of environmental samples from objects owned by hospitalised patients (e.g., clothes, mobile phones) or from households or businesses including farms. Access to personal objects or entrance to private property would typically require consent, although local public health powers may legally permit such testing without consent.

Ethical issues related to environmental testing include the identifiability of human individuals and the details of their infection even if the sample was not taken directly from such individuals. This can occur, for example, with pathogen sequencing (whereby the genomics of specific infections can later be linked back to individuals) and/or metagenomic testing (which can detect human DNA as well as pathogen genomes). The privacy of individuals should be protected insofar as possible, in part because individuals may face stigma due to testing and/or being found to be positive for an infectious disease.

[1] In the context of this protocol, wastewater surveillance is not included.

In all cases, sampling practices should be consistent with any relevant country level regulations. Where such regulations are lacking and testing is urgent (e.g., during an outbreak), advice should be sought from national public health agencies. While consent may be required for collection of certain types of samples, consent is not typically required for public health uses of samples (e.g., any testing for the purposes of outbreak investigation). If samples area also used for research purposes (in addition to public health use), standard research ethics requirements apply.

Informed consent is required in the instance that individual patient data needs to be collected – and it has not yet been collected (or will not be collected) through any other MERS-CoV investigation. In that case, informed consent should be sought from the MERS patient hospitalized in the health-care facility, if they are willing to participate in the investigation. This should be conducted before any procedure is performed, as part of the investigation by a trained member of the investigation team.

The purpose of the investigation should be explained to the MERS patients, and informed consent should seek approval to collect demographic data and clinical information related to MERS-CoV and their current hospitalization (if necessary).

Consent, or assent for children under the legal age of consent, will be obtained according to the country's national ethical requirements and thus need to comply with local regulations:

- **Consent** for:
  - adults; and
  - children under the legal age of consent (usually this is 18 years but it will vary from country to country) from a parent or legal guardian.

Implementation tip The age of consent may vary by country. Check the requirements of local, regional or national authorities.

- **Assent** from:
  - children and adolescents under the legal age of consent, but who can understand the implications of informed consent and go through the necessary procedures. This is usually children over the age of 12 to 13 years, but this will vary from country to country. A consent form from a parent or legal guardian will also be collected.

All eligible individuals, regardless of whether or not they are very unwell should be considered for participation in the investigation. For individuals who lack the decisional capacity to consent at the time of the investigation, consent or assent by proxy (parent or guardian or spouse or family member) may be considered so as to not unduly exclude individuals from participating in the investigation.

An appropriately trained member of the investigation team will need to explain to each participant that participation in the investigation is voluntary and that they are free to withdraw, without justification, from the investigation at any time without consequences and without it affecting the care that they receive at the health-care facility. A member of the investigation must also be able to answer any questions individuals may have related to the procedures of the investigation.

The processes related to withdrawal of a participant need to be described both in the protocol and in the information for the participant. In this description it must be made clear that a participant can withdraw from the investigation, without justification, at any time by informing one of the members of the investigation team. The contact details of one of the members of the investigation need to be provided in the information for the participant. If any participant decides to withdraw during the investigation, the samples collected and data should be discarded, except if the participant indicates that these can be kept for the purpose of conducting the investigation, or for future studies of other infectious pathogens.

Implementation tip Additional consent forms may need to be developed by the country, according to national laws and regulations, if the investigation calls for storage and future use of samples.

2.7.2 Risks and benefits for participants

This investigation poses no risk to participants, as no collection of biological specimens is involved. The primary benefit of the study is indirect in that data collected will help improve and guide efforts to understand the role of environmental contamination in the transmission of MERS-CoV and prevent further spread of MERS-CoV in healthcare facilities.

2.7.3 Confidentiality

National laws and regulations for data protection requirements must be followed.

Participant confidentiality needs to be maintained throughout the investigation. All subjects who participate in the investigation should be assigned a study identification number by the investigation team for the labelling of the questionnaire (Annex 1) and specimens. The link of this identification number to individuals will be maintained by the investigation team and the Ministry of Health (or equivalent), separately from the investigation files, and will not be disclosed elsewhere.

Data and specimens will be securely stored nationally. If the data are shared by the implementing organization with WHO or any agency or institution providing support for data analysis, data shared will include only the investigation identification number and not

any identifiable information. Data sharing outside the country will be managed according to national laws and regulations, as appropriate.

Article 45 of the IHR (2005) describes the “treatment of personal data”. Person identifiable data collected under the IHR should be kept confidential and processed anonymously, as required by national law. However, such data may be disclosed for assessments and management of public health risks, provided the data are processed fairly and lawfully.

2.7.4 Prevention of MERS-CoV infection in health and care workers

Before the start of the investigation, all personnel involved in the investigation need to be trained in IPC procedures (standard contact and droplet precautions, as determined by national or local guidelines). These procedures should include proper hand hygiene and the correct use of PPE (such as surgical or respiratory face masks, gloves, etc.), as per national or local guidelines, provided to members of the investigation team, not only to minimize their own risk of infection when in close contact with individuals with high-risk for MERS-CoV, but also to minimize the risk of spread among other participants in the investigation. Any investigation personnel who develop symptoms consistent with MERS-CoV should be immediately isolated, tested with a nasopharyngeal and oropharyngeal swab and managed as a suspect case of MERS-CoV according to the national or local guidelines.

WHO technical guidance on IPC specific to MERS-CoV can be found on the WHO website *(52)*.

3. Dissemination of results

The health authority in the region in which the investigation is implemented, and the Ministry of Health (or equivalent) should receive a report on the overall findings of the investigation. This should include the following information:

(1) The study design and specific procedures used (e.g. sampling methods, laboratory techniques);

(2) Contextual (background) information related to the MERS patient that has been admitted to the health-care facility, the characteristics of the health-care facility (including IPC procedures in place), etc.;

(3) The number of potentially contaminated samples tested and the number of samples confirmed to test positive for MERS-CoV;

(4) Any other key findings, as per specific study objectives and characteristics implemented (e.g. persistence of MERS-CoV by surface, successful virus isolation).

An integrated approach which engages both researchers and stakeholders should be used for conducting dissemination activities in joint efforts by the researchers involved and advisory committee members.

Dissemination activities could include:

- Submitting progress and final research reports to regional health authorities, national Ministries of Health and to WHO.
- Publishing the research findings as preprints and subsequently in peer-reviewed journals and making them available in open access format.
- Organizing meetings, seminars and workshops involving a panel of the research team beside other research experts (from human and animal health) to discuss the research findings and how they may influence public health interventions and policies.
- Developing policy briefs for national health authorities.
- Submitting genomic sequence information into international databases.

Implementation tip The *timely* dissemination of the results of this study are critical in understanding transmission of the MERS-CoV virus to inform guidance for policy to direct national and international public health responses.

4. Composition of study team

This investigation calls for a multi-disciplinary research study team to undertake this study. The composition of the study team will be determined by each country. It is recommended that members from the Ministry of Health, national laboratories and other partners are included in the implementation and interpretation of this investigation. Coordination of all MERS-CoV investigations and sharing of information in real-time will be needed at both country and global levels. Epidemiologists, modellers, virologists, statisticians, clinicians and public health experts will all be necessary to include in this study to define key virological parameters of MERS-CoV.

Implementation tip A table such as the one below may be useful for designating roles and responsibilities, and identifying study partners, during the planning stage of this investigation.

Table 2. Coordination matrix of roles and responsibilities in Country X

What?	Who?
Overall coordination of the investigation	*[Cite institution and/or body and/or person(s)]*
Sample collection	*[Cite institution and/or body and/or person(s)]*
Interview of MERS patient or proxy (optional)	*[Cite institution and/or body and/or person(s)]*
Laboratory analysis	*[Cite institution and/or body and/or person(s)]*
Data analysis	*[Cite institution and/or body and/or person(s)]*
Data management	*[Cite institution and/or body and/or person(s)]*
IT management	*[Cite institution and/or body and/or person(s)]*
Communication of overall findings of investigation	*[Cite institution and/or body and/or person(s)]*
[add more roles, as per country context]	*[Cite institution and/or body and/or person(s)]*

Once a study team is identified, a workshop and training should be conducted to familiarize the team with the objectives and organize the implementation of the study.

5. References

1. Zaki AM, van Boheemen S, Bestebroer TM, Osterhaus AD, Fouchier RA. Isolation of a novel coronavirus from a man with pneumonia in Saudi Arabia. N Engl J Med. 2012;367(19):1814-20.

2. World Health Organization. Middle East respiratory syndrome: global summary and assessment of risk – 16 November 2022. Available from: https://iris.who.int/handle/10665/364525.

3. Alraddadi BM, Watson JT, Almarashi A, Abedi GR, Turkistani A, Sadran M, et al. Risk Factors for Primary Middle East Respiratory Syndrome Coronavirus Illness in Humans, Saudi Arabia, 2014. Emerg Infect Dis. 2016;22(1):49-55.

4. Madani TA, Azhar EI, Hashem AM. Evidence for camel-to-human transmission of MERS coronavirus. N Engl J Med. 2014;371(14):1360.

5. Drosten C, Kellam P, Memish ZA. Evidence for camel-to-human transmission of MERS coronavirus. N Engl J Med. 2014;371(14):1359-60.

6. Azhar EI, El-Kafrawy SA, Farraj SA, Hassan AM, Al-Saeed MS, Hashem AM, et al. Evidence for camel-to-human transmission of MERS coronavirus. N Engl J Med. 2014;370(26):2499-505.

7. Islam MM, Khanom H, Farag E, Mim ZT, Naidoo P, Mkhize-Kwitshana ZL, et al. Global patterns of Middle East respiratory syndrome coronavirus (MERS-CoV) prevalence and seroprevalence in camels: A systematic review and meta-analysis. One Health. 2023;16:100561.

8. Food and Agricultural Organization of the United Nations. Global technical meeting on MERS-CoV and other emerging zoonotic coronaviruses – meeting summary. 2021. Available from: https://www.who.int/publications/m/item/global-technical-meeting-on-mers-cov-and-other-emerging-zoonotic-coronaviruses-meeting-summary

9. Al-Tawfiq JA, Auwaerter PG. Healthcare-associated infections: the hallmark of Middle East respiratory syndrome coronavirus with review of the literature. J Hosp Infect. 2019;101(1):20-9.

10. Oboho IK, Tomczyk SM, Al-Asmari AM, Banjar AA, Al-Mugti H, Aloraini MS, et al. 2014 MERS-CoV outbreak in Jeddah--a link to health care facilities. N Engl J Med. 2015;372(9):846-54.

11. Hastings DL, Tokars JI, Abdel Aziz IZ, Alkhaldi KZ, Bensadek AT, Alraddadi BM, et al. Outbreak of Middle East Respiratory Syndrome at Tertiary Care Hospital, Jeddah, Saudi Arabia, 2014. Emerg Infect Dis. 2016;22(5):794-801.

12. Kim KH, Tandi TE, Choi JW, Moon JM, Kim MS. Middle East respiratory syndrome coronavirus (MERS-CoV) outbreak in South Korea, 2015: epidemiology, characteristics and public health implications. J Hosp Infect. 2017;95(2):207-13.

13. Balkhy HH, Alenazi TH, Alshamrani MM, Baffoe-Bonnie H, Al-Abdely HM, El-Saed A, et al. Notes from the Field: Nosocomial Outbreak of Middle East Respiratory Syndrome in a Large Tertiary Care Hospital--Riyadh, Saudi Arabia, 2015. MMWR Morb Mortal Wkly Rep. 2016;65(6):163-4.

14. Guery B, Poissy J, el Mansouf L, Sejourne C, Ettahar N, Lemaire X, et al. Clinical features and viral diagnosis of two cases of infection with Middle East Respiratory Syndrome coronavirus: a report of nosocomial transmission. Lancet. 2013;381(9885):2265-72.

15. World Health Organization. WHO MERS Global Summary and Assessment of Risk. 2019. Available from: https://apps.who.int/iris/handle/10665/326126

16. Health Protection Agency U. K. Novel Coronavirus Investigation team. Evidence of person-to-person transmission within a family cluster of novel coronavirus infections, United Kingdom, February 2013. Euro Surveill. 2013;18(11):20427.

17. Omrani AS, Matin MA, Haddad Q, Al-Nakhli D, Memish ZA, Albarrak AM. A family cluster of Middle East Respiratory Syndrome Coronavirus infections related to a likely unrecognized asymptomatic or mild case. Int J Infect Dis. 2013;17(9):e668-72.

18. Abroug F, Slim A, Ouanes-Besbes L, Hadj Kacem MA, Dachraoui F, Ouanes I, et al. Family cluster of Middle East respiratory syndrome coronavirus infections, Tunisia, 2013. Emerg Infect Dis. 2014;20(9):1527-30.

19. Drosten C, Meyer B, Muller MA, Corman VM, Al-Masri M, Hossain R, et al. Transmission of MERS-coronavirus in household contacts. N Engl J Med. 2014;371(9):828-35.

20. Arwady MA, Alraddadi B, Basler C, Azhar EI, Abuelzein E, Sindy AI, et al. Middle East Respiratory Syndrome Coronavirus Transmission in Extended Family, Saudi Arabia, 2014. Emerg Infect Dis. 2016;22(8):1395-402.

21. Al Hosani FI, Kim L, Khudhair A, Pham H, Al Mulla M, Al Bandar Z, et al. Serologic Follow-up of Middle East Respiratory Syndrome Coronavirus Cases and Contacts-Abu Dhabi, United Arab Emirates. Clin Infect Dis. 2019;68(3):409-18.

22. Alanazi KH, Killerby ME, Biggs HM, Abedi GR, Jokhdar H, Alsharef AA, et al. Scope and extent of healthcare-associated Middle East respiratory syndrome coronavirus transmission during two contemporaneous outbreaks in Riyadh, Saudi Arabia, 2017. Infect Control Hosp Epidemiol. 2019;40(1):79-88.

23. Van Kerkhove MD, Alaswad S, Assiri A, Perera R, Peiris M, El Bushra HE, et al. Transmissibility of MERS-CoV Infection in Closed Setting, Riyadh, Saudi Arabia, 2015. Emerg Infect Dis. 2019;25(10):1802-9.

24. Memish ZA, Zumla AI, Al-Hakeem RF, Al-Rabeeah AA, Stephens GM. Family cluster of Middle East respiratory syndrome coronavirus infections. N Engl J Med. 2013;368(26):2487-94.

25. Balkhy HH, Alenazi TH, Alshamrani MM, Baffoe-Bonnie H, Arabi Y, Hijazi R, et al. Description of a Hospital Outbreak of Middle East Respiratory Syndrome in a Large Tertiary Care Hospital in Saudi Arabia. Infect Control Hosp Epidemiol. 2016;37(10):1147-55.

26. Bin SY, Heo JY, Song MS, Lee J, Kim EH, Park SJ, et al. Environmental Contamination and Viral Shedding in MERS Patients During MERS-CoV Outbreak in South Korea. Clin Infect Dis. 2016;62(6):755-60.

27. Khan RM, Al-Dorzi HM, Al Johani S, Balkhy HH, Alenazi TH, Baharoon S, et al. Middle East respiratory syndrome coronavirus on inanimate surfaces: A risk for health care transmission. Am J Infect Control. 2016;44(11):1387-9.

28. Kim SH, Chang SY, Sung M, Park JH, Bin Kim H, Lee H, et al. Extensive Viable Middle East Respiratory Syndrome (MERS) Coronavirus Contamination in Air and Surrounding Environment in MERS Isolation Wards. Clin Infect Dis. 2016;63(3):363-9.

29. Azhar EI, Hashem AM, El-Kafrawy SA, Sohrab SS, Aburizaiza AS, Farraj SA, et al. Detection of the Middle East respiratory syndrome coronavirus genome in an air sample originating from a camel barn owned by an infected patient. mBio. 2014;5(4):e01450-14.

30. van Doremalen N, Bushmaker T, Munster VJ. Stability of Middle East respiratory syndrome coronavirus (MERS-CoV) under different environmental conditions. Euro Surveill. 2013;18(38):20590.

31. van Doremalen N, Letko M, Fischer RJ, Bushmaker T, Schulz J, Yinda CK, et al. Surface–Aerosol Stability and Pathogenicity of Diverse Middle East Respiratory Syndrome Coronavirus Strains, 2012–2018. Emerg Infect Dis. 2021;27(12):3052-62.

32. Adhikari U, Chabrelie A, Weir M, Boehnke K, McKenzie E, Ikner L, et al. A Case Study Evaluating the Risk of Infection from Middle Eastern Respiratory Syndrome Coronavirus (MERS-CoV) in a Hospital Setting Through Bioaerosols. Risk Anal. 2019;39(12):2608-24.

33. Oraby T, Tyshenko MG, Balkhy HH, Tasnif Y, Quiroz-Gaspar A, Mohamed Z, et al. Analysis of the Healthcare MERS-CoV Outbreak in King Abdulaziz Medical Center, Riyadh, Saudi

Arabia, June-August 2015 Using a SEIR Ward Transmission Model. Int J Environ Res Public Health. 2020;17(8):2936.

34. Jung M, Chung WJ, Sung M, Jo S, Hong J. Analysis of Infection Transmission Routes through Exhaled Breath and Cough Particle Dispersion in a General Hospital. Int J Environ Res Public Health. 2022;19(5):2512.

35. US Centers for Disease Control and Prevention. Guidelines for Environmental Infection Control in Health-Care Facilities. Atlanta, GA; 2019 July 2019. Available from: https://www.cdc.gov/infection-control/media/pdfs/guideline-environmental-h.pdf?CDC_AAref_Val=https://www.cdc.gov/infectioncontrol/pdf/guidelines/environmental-guidelines-P.pdf

36. Vikke HS, Giebner M, Kolmos HJ. Prehospital infection control and prevention in Denmark: a cross-sectional study on guideline adherence and microbial contamination of surfaces. Scand J Trauma Resusc Emerg Med. 2018;26(1):71.

37. Huslage K, Rutala WA, Sickbert-Bennett E, Weber DJ. A quantitative approach to defining "high-touch" surfaces in hospitals. Infect Control Hosp Epidemiol. 2010;31(8):850-3.

38. US Centers for Disease Control and Prevention. Options for Evaluating Environmental Cleaning. 2010. Available from: https://www.cdc.gov/infection-control/php/evaluating-environmental-cleaning/?CDC_AAref_Val=https://www.cdc.gov/hai/toolkits/evaluating-environmental-cleaning.html

39. Julian TR, Tamayo FJ, Leckie JO, Boehm AB. Comparison of surface sampling methods for virus recovery from fomites. Appl Environ Microbiol. 2011;77(19):6918-25.

40. Tran K, Cimon K, Severn M, Pessoa-Silva C, Conly J. Aerosol-generating procedures and risk of transmission of acute respiratory infections: a systematic review. CADTH Technol Overv. 2013;3(1):e3201.

41. Tran K, Cimon K, Severn M, Pessoa-Silva CL, Conly J. Aerosol generating procedures and risk of transmission of acute respiratory infections to healthcare workers: a systematic review. PLoS One. 2012;7(4):e35797.

42. Overton E. The Journal of Infection Control Nursing. Bed-making and bacteria. Nurs Times. 1988;84(9):69-71.

43. Shiomori T, Miyamoto H, Makishima K, Yoshida M, Fujiyoshi T, Udaka T, et al. Evaluation of bedmaking-related airborne and surface methicillin-resistant Staphylococcus aureus contamination. J Hosp Infect. 2002;50(1):30-5.

44. Haagmans BL, Al Dhahiry SH, Reusken CB, Raj VS, Galiano M, Myers R, et al. Middle East respiratory syndrome coronavirus in dromedary camels: an outbreak investigation. Lancet Infect Dis. 2014;14(2):140-5.

45. World Health Organization. WHO guidelines on hand hygiene in health care 2009 [Available from: https://www.who.int/publications/i/item/9789241597906].

46. World Health Organization. Laboratory Testing for Middle East Respiratory Syndrome Coronavirus, Interim guidance (revised), January 2018 2018 [Available from: https://iris.who.int/bitstream/handle/10665/259952/WHO-MERS-LAB-15.1-Rev1-2018-eng.pdf.

47. World Health Organization. Guidance on regulations for the transport of infectious substances 2021-2022 2021 [Available from: https://www.who.int/publications/i/item/9789240019720.

48. Corman VM, Eckerle I, Bleicker T, Zaki A, Landt O, Eschbach-Bludau M, et al. Detection of a novel human coronavirus by real-time reverse-transcription polymerase chain reaction. Euro Surveill. 2012;17(39):20285.

49. Lu X, Whitaker B, Sakthivel SK, Kamili S, Rose LE, Lowe L, et al. Real-time reverse transcription-PCR assay panel for Middle East respiratory syndrome coronavirus. J Clin Microbiol. 2014;52(1):67-75.

50. Corman VM, Muller MA, Costabel U, Timm J, Binger T, Meyer B, et al. Assays for laboratory confirmation of novel human coronavirus (hCoV-EMC) infections. Euro Surveill. 2012;17(49):20334.

51. World Health Organization. WHO guidelines on ethical issues in public health surveillance 2017 [Available from: https://www.who.int/publications/i/item/9789241512657.

52. World Health Organization. Infection prevention and control during health care for probable or confirmed cases of Middle East respiratory syndrome coronavirus (MERS-CoV) infection. Interim guidance (15 October 2019) 2019 [Available from: https://www.who.int/publications/i/item/10665-174652].

6. Annexes

Annex 1: Questionnaire: Epidemiological and clinical information from MERS-CoV patient

To be conducted only if necessary due to no other case-investigations being carried out for this MERS-CoV positive case.

Implementation tip As part of study implementation, it is important to allocate time and study funds for translation and field-testing of the questionnaires and other data collection tools. Investigators are encouraged to adapt the questionnaires to local contexts to maximize the relevance of the study's results.

Unique Case ID and Cluster number (if applicable):

1. Participant classification

Vital status: ☐ Alive ☐ Deceased ☐ Unknown

2. Data collector and interview information

Name of data collector	
Data collector profession	
Data collector institution	
Data collector telephone number	
Data collector email	
Place of interview (region, city, further details if applicable)	
Interview start date (dd/mm/yyyy)	____/____/____
Form completion date (dd/mm/yyyy)	____/____/____
Language used for interview	

3. Participant personally identifying information

(Note: personally identifying data should be stored securely and separately from other parts of this form)

First name	
Family name	
Date of birth (dd/mm/yyyy)	____/____/____ ☐ Unknown
Address (if multiple residences, give addresses for all)	
Telephone (mobile) number	
Email	
National identifier / social number [optional]	
Responsible health centre, if applicable (name, address, contact information):	

Questionnaire: Epidemiological and clinical information from MERS-CoV patient (continued)

4. Interview respondent information (→ only if the person providing the information is not the patient) *(Note: personally identifying data should be stored securely and separately from other parts of this form)*	
First name	
Family name	
Sex	☐ Male ☐ Female ☐ Not known ☐ Prefer not to answer
Date of birth (dd/mm/yyyy)	____/____/____ ☐ Unknown
Relationship to patient	
Respondent address	
Telephone (mobile) number	
Email	

5. MERS patient demographic information	
Sex	☐ Male ☐ Female ☐ Not known ☐ Prefer not to answer
Age (years, months)	____ years ____ months ☐ Unknown
Nationality	
Ethnicity *[optional, at discretion of study investigators. If using, please input checkbox style options with relevant ethnicities in the right-hand column]*	
Country of residence	
Occupation (select all that apply and specify location/ facility)	☐ Health worker ☐ Health laboratory worker ☐ Working with dromedary camels → if Yes, specify in what capacity: ☐ Working with other livestock (not dromedary camels) → if Yes, specify in what capacity: ☐ Student ☐ Other, specify: For each occupation, please specify location or facility:

6a. Patient symptoms (from date of onset of symptoms)	
Date of first symptom onset (dd/mm/yyyy)	____/____/____ ☐ No symptoms ☐ Unknown
Fever (≥38 °C) or history of fever	☐ Yes ☐ No ☐ Unknown If Yes, specify maximum temperature: °C
Date of first health facility visit (including traditional care) (dd/mm/yyyy)	____/____/____ ☐ Not applicable (na) ☐ Unknown
Total health facilities visited to date	Specify number, locations, names: ☐ na ☐ Unknown

Questionnaire: Epidemiological and clinical information from MERS-CoV patient (continued)

6b. Respiratory symptoms	
Dry cough	☐ Yes ☐ No ☐ Unknown If Yes, date of onset (dd/mm/yyyy): ____/____/____
Productive cough	☐ Yes ☐ No ☐ Unknown If Yes, date of onset (dd/mm/yyyy): ____/____/____
Phlegm	☐ Yes ☐ No ☐ Unknown If Yes, date of onset (dd/mm/yyyy): ____/____/____
Sore throat	☐ Yes ☐ No ☐ Unknown If Yes, date of onset (dd/mm/yyyy): ____/____/____
Runny nose	☐ Yes ☐ No ☐ Unknown If Yes, date of onset (dd/mm/yyyy): ____/____/____
Shortness of breath	☐ Yes ☐ No ☐ Unknown If Yes, date of onset (dd/mm/yyyy): ____/____/____
Chest pain	☐ Yes ☐ No ☐ Unknown If Yes, date of onset (dd/mm/yyyy): ____/____/____
6c. Other symptoms	
Chills	☐ Yes ☐ No ☐ Unknown
Vomiting	☐ Yes ☐ No ☐ Unknown
Nausea	☐ Yes ☐ No ☐ Unknown
Diarrhoea	☐ Yes ☐ No ☐ Unknown
Headache	☐ Yes ☐ No ☐ Unknown
Rash	☐ Yes ☐ No ☐ Unknown
Conjunctivitis	☐ Yes ☐ No ☐ Unknown
Muscle aches	☐ Yes ☐ No ☐ Unknown
Joint ache	☐ Yes ☐ No ☐ Unknown
Loss of appetite	☐ Yes ☐ No ☐ Unknown
Fatigue	☐ Yes ☐ No ☐ Unknown
Seizures	☐ Yes ☐ No ☐ Unknown
Altered consciousness	☐ Yes ☐ No ☐ Unknown
Other neurological signs	☐ Yes ☐ No ☐ Unknown If Yes, specify:
Other symptoms	☐ Yes ☐ No ☐ Unknown If Yes, specify:

Questionnaire: Epidemiological and clinical information from MERS-CoV patient (continued)

7. Patient medical history – pre-existing conditions and chronic illnesses	
Pregnancy	☐ Yes ☐ No ☐ Unknown If Yes, specify number of weeks:
Recent pregnancy – if female and not currently pregnant, was the patient pregnant in the last 6 months?	☐ Yes ☐ No ☐ Unknown
Obesity	☐ Yes ☐ No ☐ Unknown
Cancer	☐ Yes ☐ No ☐ Unknown
Diabetes	☐ Yes ☐ No ☐ Unknown
HIV/other immune deficiency	☐ Yes ☐ No ☐ Unknown
Heart disease	☐ Yes ☐ No ☐ Unknown
Asthma (requiring medication)	☐ Yes ☐ No ☐ Unknown
Chronic lung disease (non-asthma)	☐ Yes ☐ No ☐ Unknown
Chronic liver disease	☐ Yes ☐ No ☐ Unknown
Chronic haematological disorder	☐ Yes ☐ No ☐ Unknown
Chronic kidney disease	☐ Yes ☐ No ☐ Unknown
Chronic neurological impairment/disease	☐ Yes ☐ No ☐ Unknown
Organ or bone marrow recipient	☐ Yes ☐ No ☐ Unknown
Familial hereditary illness	☐ Yes ☐ No ☐ Unknown If Yes, specify:
Other pre-existing condition(s)	☐ Yes ☐ No ☐ Unknown If Yes, specify:

8. Possible MERS-CoV exposures in the 14 days before symptom onset	
Patient travelled domestically within the last 14 days	☐ Yes ☐ No ☐ Unknown If Yes, dates of travel (dd/mm/yyyy): ____/____/____ to ____/____/____ Regions visited: Cities visited:
Patient travelled internationally within the last 14 days	☐ Yes ☐ No ☐ Unknown If Yes, dates of travel (dd/mm/yyyy): ____/____/____ to ____/____/____ Countries visited: Cities visited:
In the past 14 days, have you had contact with anyone with suspected or confirmed MERS-CoV infection?	☐ Yes ☐ No ☐ Unknown If Yes, dates of last contact (dd/mm/yyyy): ____/____/____

Questionnaire: Epidemiological and clinical information from MERS-CoV patient (continued)

Patient attended festival or mass gathering in the past 14 days	☐ Yes ☐ No ☐ Unknown If Yes, specify:
Patient exposed to person with similar illness in the past 14 days	☐ Yes ☐ No ☐ Unknown If Yes, location of exposure: ☐ Home ☐ Hospital ☐ Workplace ☐ Tour group ☐ School ☐ Unknown ☐ Other, specify:
Patient visited or was admitted to inpatient health facility in the past 14 days, prior to onset of current illness	☐ Yes ☐ No ☐ Unknown If Yes, specify:
Patient visited outpatient treatment facility in the past 14 days, prior to onset of current illness	☐ Yes ☐ No ☐ Unknown If Yes, specify:
Patient visited traditional healer in the past 14 days, prior to onset of current illness	☐ Yes ☐ No ☐ Unknown If Yes, specify type:

Questionnaire: Epidemiological and clinical information from MERS-CoV patient (continued)

9a. Molecular testing methods and results:							
Complete a new line for each specimen collected and each type of test conducted:							
Laboratory identification number	**Date sample collected (dd/mm/yyyy)**	**Date sample received (dd/mm/yyyy)**	**Type of sample**	**Type of test**	**Result**	**Result date (dd/mm/yyyy)**	**Specimens shipped to other laboratory for confirmation**
	____/____/____	____/____/____	☐ Nasal swab ☐ Throat swab ☐ Nasopharyngeal swab ☐ Other, specify:	☐ Polymerase chain reaction (PCR) ☐ Whole genome sequencing ☐ Partial genome sequencing ☐ Other, specify	☐ positive for MERS-CoV ☐ negative for MERS-CoV ☐ inconclusive ☐ positive for other pathogens Please specify which pathogens: Results of phylogenetic analysis: _____	____/____/____	☐ No ☐ Yes If Yes, specify date ____/____/____ If Yes, name of the laboratory: _____ ***Genomic sequencing*** ☐ No ☐ Yes (locally) ☐ Yes (shipped to external laboratory) If Yes to shipped externally, specify date ____/____/____ If Yes to shipped externally name of the laboratory: _____

Questionnaire: Epidemiological and clinical information from MERS-CoV patient (continued)

9b. Serology testing methods and results:

Complete a new line for each specimen collected and each type of test conducted:

Laboratory identification number	Date sample collected (dd/mm/yyyy)	Date sample received (dd/mm/yyyy)	Type of sample	Type of test	Result (MERS-CoV antibody titres)	Result date (dd/mm/yyyy)	Specimens shipped to other laboratory for confirmation
	____/____/____	____/____/____	☐ Serum ☐ Other, specify:	Specify type (enzyme linked immunosorbent assay – ELISA, indirect fluorescent antibody assay – IFA, neutralization assay, etc.):	☐ positive If positive, titre: ☐ negative ☐ inconclusive	____/____/____	☐ Yes If Yes, specify date ____/____/____ If Yes, name of the laboratory: ____ ☐ No

Questionnaire: Epidemiological and clinical information from MERS-CoV patient (continued)

10. Status of form completion	
Form completed	☐ Yes ☐ No or partially If No or partially, reason: ☐ Missed ☐ Not attempted ☐ Not performed ☐ Refusal ☐ Other, specify:

Annex 2: Sampling log for multiple surface sites

Sampling log for multiple surface sites (Note: It is preferable to have a designated individual fill out the log daily to minimize errors)								
Date		Day 1 Date (dd/mm/yyyy) ____/____/____	Day 2 Date (dd/mm/yyyy) ____/____/____	Day 3 Date (dd/mm/yyyy) ____/____/____	Day 4 Date (dd/mm/yyyy) ____/____/____	Day 5 Date (dd/mm/yyyy) ____/____/____	Day 6 Date (dd/mm/yyyy) ____/____/____	Day 7 Date (dd/mm/yyyy) ____/____/____
Laboratory ID Nr								
Site Type	**Patient entry**	☐ Ambulance	☐ Ambulance	☐ Ambulance	☐ Ambulance	☐ Ambulance	☐ Ambulance	☐ Ambulance
		☐ Entrance	☐ Entrance	☐ Entrance	☐ Entrance	☐ Entrance	☐ Entrance	☐ Entrance
		☐ Corridor	☐ Corridor	☐ Corridor	☐ Corridor	☐ Corridor	☐ Corridor	☐ Corridor
		☐ Waiting room	☐ Waiting room	☐ Waiting room	☐ Waiting room	☐ Waiting room	☐ Waiting room	☐ Waiting room
		☐ Elevator	☐ Elevator	☐ Elevator	☐ Elevator	☐ Elevator	☐ Elevator	☐ Elevator
		☐ X-ray room	☐ X-ray room	☐ X-ray room	☐ X-ray room	☐ X-ray room	☐ X-ray room	☐ X-ray room
		Other: Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….
	Hospital staff	☐ Staff room	☐ Staff room	☐ Staff room	☐ Staff room	☐ Staff room	☐ Staff room	☐ Staff room
		☐ Ante room	☐ Ante room	☐ Ante room	☐ Ante room	☐ Ante room	☐ Ante room	☐ Ante room
		☐ Patient room	☐ Patient room	☐ Patient room	☐ Patient room	☐ Patient room	☐ Patient room	☐ Patient room
		Other: Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….
	Air flow	☐ Patient room	☐ Patient room	☐ Patient room	☐ Patient room	☐ Patient room	☐ Patient room	☐ Patient room
		☐ Patient bathroom	☐ Patient bathroom	☐ Patient bathroom	☐ Patient bathroom	☐ Patient bathroom	☐ Patient bathroom	☐ Patient bathroom
		Other: Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….	***Other:*** Specify ….

Sample Type	☐ Moistened swab	☐ Moistened swab	☐ Moistened swab	☐ Moistened swab	☐ Moistened swab	☐ Moistened swab	☐ Moistened swab
	☐ Moistened sponge	☐ Moistened sponge	☐ Moistened sponge	☐ Moistened sponge	☐ Moistened sponge	☐ Moistened sponge	☐ Moistened sponge
	☐ Moistened wipe	☐ Moistened wipe	☐ Moistened wipe	☐ Moistened wipe	☐ Moistened wipe	☐ Moistened wipe	☐ Moistened wipe
	☐ Direct immersion	☐ Direct immersion	☐ Direct immersion	☐ Direct immersion	☐ Direct immersion	☐ Direct immersion	☐ Direct immersion
	☐ Containment	☐ Containment	☐ Containment	☐ Containment	☐ Containment	☐ Containment	☐ Containment
	☐ RODAC	☐ RODAC	☐ RODAC	☐ RODAC	☐ RODAC	☐ RODAC	☐ RODAC
Test	☐ PCR ☐ Cell culture	☐ PCR ☐ Cell culture	☐ PCR ☐ Cell culture	☐ PCR ☐ Cell culture	☐ PCR ☐ Cell culture	☐ PCR ☐ Cell culture	☐ PCR ☐ Cell culture
	Other: Specify ….	Other: Specify ….	Other: Specify ….	Other: Specify ….	Other: Specify ….	Other: Specify ….	Other: Specify ….
Results	☐ POS for MERS-CoV	☐ POS for MERS-CoV	☐ POS for MERS-CoV	☐ POS for MERS-CoV	☐ POS for MERS-CoV	☐ POS for MERS-CoV	☐ POS for MERS-CoV
	☐ NEG for MERS-CoV	☐ NEG for MERS-CoV	☐ NEG for MERS-CoV	☐ NEG for MERS-CoV	☐ NEG for MERS-CoV	☐ NEG for MERS-CoV	☐ NEG for MERS-CoV
	☐ POS for other pathogens; specify:	☐ POS for other pathogens; specify:	☐ POS for other pathogens; specify:	☐ POS for other pathogens; specify:	☐ POS for other pathogens; specify:	☐ POS for other pathogens; specify:	☐ POS for other pathogens; specify:

Emerging Diseases and Zoonoses Unit
Epidemic and Pandemic Preparedness and Prevention Department
20, Avenue Appia
1211 Geneva 27
Switzerland
Email: MERSHQ@who.int
Website: https://www.who.int/initiatives
/mers-cov-investigations-and-studies